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THE ADVANCEMENT OF SCIENCE

VOL. V, No. 18 JULY, 1948

CONTENTS

PAGE

OFFICERS AND COUNCIL 74

BRIGHTON 75

SECTIONAL OFFICERS 76

MODERN METHODS OF COMPUTATION 79

Report of a Discussion : Dr. J. C. P. Miller, 79—Mr. J. R. Womersley, 83—Mr. J. H. Wilkinson, 85—Dr. J. M. Jackson, 85—Dr. L. Fox, 85.

BIOCHEMICAL APPLICATIONS OF STABLE AND RADIOACTIVE ISOTOPES

By Dr. A. S. McFarlane 86

INSECTICIDES 89

Report of a Discussion : Mr. C. T. Gimingham, O.B.E., 89—Prof. J. W. Munro, 92—Dr. J. L. Gunn, 92—Dr. C. Potter, 94—Dr. V. B. Wigglesworth, F.R.S., 94.

PAGE

HUMAN FACTORS IN INDUSTRY 96

Working Conditions : Prof. R. E. Lane, 96—Dr. C. L. Cope, 99—Mr. H. C. Weston, 101—Dr. T. Bedford, 103, *Human Relations :* Dr. R. F. Tredgold, 107—Mr. D. Chapman, 109—Dr. A. T. M. Wilson, 111—Mr. Alec Rodger,116.

INCENTIVES 119

Report of a Discussion : Dr. J. A. Bowie, 119—Mr. Charles Madge, 120—Mr. D. Chapman, 120—Mrs. W. Raphael, 121—Miss N. M. Davis, 122.

THE INDUSTRIAL DEVELOPMENT OF DUNDEE

By Sir Garnet Wilson 123

VILLAGE PLANNING IN SCOTLAND 1745–1845

By Mr. J. M. Houston 129

ABSTRACTS OF COMMUNICATIONS READ TO PSYCHOLOGY SECTION 133

THE IDEAL GEOLOGICAL MAP

By Prof. D. L. Linton 141

LOCATION OF THUNDERSTORMS

By Dr. R. L. Smith-Rose 149

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BRIGHTON

THE next annual meeting of the Association will be held in Brighton from September 8–15, under the Presidency of Sir Henry Tizard, K.C.B., F.R.S. A Preliminary Programme of the Meeting has been published and has been sent to all readers of this Journal who are likely to be interested. Further copies are available and will be sent on request to any addresses of which the Secretary may be notified. The full programme will be despatched during the third week in August to all who have intimated their intention to be present. It has been emphasised in the Preliminary Programme that living accommodation provisionally reserved for members cannot be held indefinitely at the disposal of the Association's Agents and it may be difficult to make firm reservations for those who delay registration. For this reason and also to enable adequate arrangements to be made for social and other functions it is desirable that these who intend to be present at the meeting should inform the Office as soon as possible.

All members attending the meeting will be presented on arrival at the Reception Room with an illustrated guide to Brighton. The following short history of the district has been prepared for the Association by Mr. H. D. Roberts, lately Curator of the Pavilion Estate which will be the main centre of the week's activities.

A SHORT HISTORY OF BRIGHTON

by

HENRY D. ROBERTS, M.B.E.

IN the Spring of 1928, on an eminence to the north of the town, a human skeleton was unearthed. Everything goes to show that it belonged to the 'Beaker' period of the later Neolithic or Bronze Age, and is not less than 4,000 years old. Brighton, therefore, was probably inhabited at least 4,000 years ago, and possibly man lived here long before then.

Coming to historic times, there is plenty of evidence to prove that the South Downs were populated by early agricultural communities, and the neighbourhood is rich in Roman and Romano-British remains. The foundations of a Roman Villa were exposed in 1877 at the corner of Springfield Road and Preston Road, near the Park. The Downs and the Weald contain many Saxon place names, and Saxon interments have been found not only in the surrounding district but also in Brighton itself.

In all probability the name of Brighton is of Saxon derivation, for we are told by Camden that it was called 'Brighthealmestun,' which by some is said to mean 'The sea town by the burning watch tower.' No less than 45 ways of spelling the name of the town have been recorded.

Brighton eventually came into the possession of Wulnoth, the father of Earl Godwin and the grandfather of King Harold. After the defeat of the latter at the Battle of Hastings in 1066, the town (as part of the Rape of Lewes) passed into the possession of William de Warenne, a near kinsman of the Conqueror, with whom he crossed to England and whose daughter, Gundred, he subsequently married. William Rufus created him Earl of Surrey, and the town would appear to have remained as one of the manors of the de Warennes, Earls of Surrey, until the death of the last holder of the title in 1347.

It is recorded that about the fourteenth century the inhabitants were divided into two distinct classes, the fishermen and sailors, who then formed three-quarters of the population, living under the cliffs, and those employed in agriculture who made their homes in the upper part of the town.

On July 24, 1313, Edward the Second granted a Charter to John de Warenne, the last Earl of Surrey, for markets and fairs to be held in the various manors he possessed in the Counties of Surrey and Sussex, including Reigate, Cuckfield, Ditchling, Brighton, Hurstpierpoint, Westmeston and Portslade. The Brighton market and fair continued on their duly appointed days for over 500 years as there are records of them in the middle of the eighteenth century.

The French landed at Rottingdean in 1377 and probably plundered Brighton. They also paid raiding visits in 1513 and 1514.

On July 15, 1545, according to Holinshed, the entire French navy, of '200 ships and 26 gallies,' arrived off Bright Hampsteed. One of these events is depicted in a map, the original of which is in the British Museum. Copies of this map are in the Brighton Reference Library. The map is especially interesting as showing the size of the town,

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bounded by East Street, North Street and West Street, with a ' felde in the middle of the town.'

In 1579, we are told, there were 80 fishing boats and 400 able mariners. The total population was about 2,400. Somewhere about the middle of the seventeenth century the sea began to make serious inroads and many houses under the Cliff were washed away. They were finally destroyed by great storms in 1703 and 1705.

When Charles II escaped from England, after the battle of Worcester, he embarked at Brighton, ' four miles off Shoreham.' He spent the previous night at the George Inn, (now demolished) the exact locality of which is a matter of conjecture. It was either in West Street or Middle Street, probably the latter. Charles was helped in his escape by Captain Nicholas Tettersell who is buried in St. Nicholas' Churchyard. His tombstone records his exploit.

In 1766 there were only six streets in the town, all to the west of the Steine, with a population of 3,600. In 1794 the population was 5,669, with fifteen streets and upwards of 1,200 houses. In 1799 there were eighteen streets with about 1,500 houses ; while the first Census, in 1801, gave a population of 7,339.

To Dr. Richard Russell is generally given the credit of having been specially instrumental in the development of the town. He was born at Lewes in 1687, and after practising at various places he built a house at Brighton, the site of which is now occupied by the Royal Albion Hotel. In 1750 he published his well-known work, *On the use of Seawater in the Diseases of the Glands.*

From now onwards inland watering places became less frequented, and Brighton appeared in the writings of the second half of the eighteenth century as a place of fashionable resort. It did not, however, reach its greatest height until it was patronised by the Prince of Wales, afterwards Prince Regent, and later George IV.

A red-letter day in the history of the town was September 7, 1783, when a visit was paid to it by the Prince of Wales, who coached down on a visit to his uncle, the Duke of Cumberland. The latter for some years previously had rented from the Duke of Marlborough a house in Brighton, the site of which is now incorporated in the Royal Pavilion. For something like 40 years the Prince erected, pulled down and re-erected the Royal Pavilion until it was completed as we know it to-day. It is not proposed to detail its history, which has been published in a separate form. After the death of George IV, in 1830, King William IV used the Royal Pavilion as a marine residence for some time. He built the present North Gate in 1832, and was constantly at Brighton. After the death of King William IV, Queen Victoria came several times to Brighton, but the Royal Pavilion was found to be too public, and Her Majesty eventually chose Osborne as her seaside home. Her children, however, were often sent to Brighton, up to 1845, and the room at the north-west angle on the first floor was at one time the bedroom of King Edward VII. The departure of Royalty from Brighton did not prevent the town from continuing to be the most fashionable seaside resort in the country.

On June 14, 1850, the Royal Pavilion was purchased from the Commissioners of Woods and Forests for the sum of £50,000, and became the property of the town. The old riding school was turned into a Corn Exchange and Skating Rink, the stables have become the Dome Concert Hall, while the Royal Pavilion proper is continually used for conferences, banquets, balls and other functions.

In 1934–35 the Dome and Corn Exchange were remodelled. The former at a cost of over £50,000, while on the latter (which ceased to be used as a Corn Exchange, although retaining its title) a sum of slightly under £34,000 was expended, including kitchen equipment. Furniture and seating for both buildings cost a further sum of £6,900 ; and a new organ was provided in the Dome for about £8,800. The seating accommodation of the Dome was increased from 1,700 to 2,800, with standing room for 200 in addition.

Brighton was incorporated in 1854, the new Council of 12 Aldermen and 36 Councillors superseding in the government of the town an unwieldy body which consisted of a Constable, 8 Headboroughs and 115 Commissioners. Of the latter, 16 retired annually to make way for 16 others. The first Mayor of the new Borough of Brighton was Mr. John Fawcett. At this time the population was about 70,000 ; in 1861 it was 77,693 ; and in 1871 it was 90,011, and the total number of houses 15,376.

The Parish of Preston lies to the North of Brighton. For various reasons efforts were made to incorporate it with Brighton. An Act of Parliament, known as ' The Brighton Borough Extension Act of 1873 ' was passed on July 7 of that year. Only that part of Preston known as East Preston was incorporated in the Borough, the dividing line being Dyke Road. The remainder of Preston, subsequently known as Preston Rural, has now been incorporated in the extended Borough of Hove. In 1871 East Preston had a population of 409, with 2,019 houses and an acreage of 1,248. In 1873 the probable

population was 450, there were 2,300 houses, and the acreage was still 1,248. The Act came into general operation on November 1, 1873. The Council of the new Borough consisted of 39 Councillors and 13 Aldermen. In 1881 the population of Brighton (including Preston) was 107,546, and there were 18,704 houses.

In 1888, Brighton became a County Borough. In 1891 the population was 115,873; in 1901, 123,478; in 1911, 131,237; in 1921, 142,427, and in 1931, 147,427. The present population (1947) is estimated to be 132,160.

In 1923, the district of Moulsecoomb, on which the Corporation had developed a Housing Estate, was added to the Borough. The Estate consisted of 94 acres and included a population of about 2,440.

On April 1, 1928, 74 years after the date of its Incorporation, the Brighton Corporation Act of 1927 came into force. This brought about a much needed extension of the town, necessitated by its rapid growth. Up to this date Brighton had, with the exception of West Ham, the greatest density of population in the United Kingdom.

The inclusion of the new areas permitted better town planning and protection of the water supply. The new area included the Parishes of Rottingdean, Ovingdean, Patcham, and part of Falmer, and took in large tracts of land, the property of the Brighton Corporation, including North Moulsecoomb Housing Estate, the Hollingbury Camp and Municipal Golf Links, and the Chattri (the Indian Memorial at Patcham). The Act passed through Parliament practically unopposed, receiving the Royal Assent on July 29, 1927. Arrangements with the surrounding local authorities were amicably settled after lengthy negotiations. Hitherto Preston had not been included in the Borough for Poor Law purposes, but since April 1, 1928, Brighton Poor Law Parish has been coterminous with the Brighton Boundaries. As a result, the following changes are now in force :—The area of Brighton has increased from 2,639 acres to 12,490 and the population to 132,160. The rateable value on the old valuation was £1,085,468; the new valuation has brought this up to £1,874,492 (1945). The sea front has increased from 2½ miles to 6, the number of Wards from 14 to 19, the number of Councillors from 42 to 57, and the number of Aldermen from 14 to 19.

The only previous meeting of the British Association in Brighton was that of the 42nd Annual Meeting held in August 1872 under the Presidency of William B. Carpenter, M.D., Ll.D., F.R.S., and during the Mayoralty of Alderman John Cordy Burrows. The attendance was 2,533. The meeting coincided with the opening of the new Aquarium which was said to ' exceed in magnitude every existing Institution of the kind.'

The following are some of the features of interest in the district.

Hill Forts

Whitehawk Camp, Neolithic, about 2000 B.C. This is one of the finest examples of a neolithic hill fort in Britain, but it has been considerably mutilated by alterations made on the Race Course which runs across part of the Camp.

Hollingbury Castle, 450–250 B.C. Recently posts have been inserted in the original stockade holes dug by the prehistoric builders of this camp. The ramparts and ditches stand out distinctly.

Devil's Dyke Camp, date uncertain, probably 300 B.C. It is the largest in area in the Brighton District.

Wolstonbury Camp, 400–300 B.C., is north of Pyecombe, a village famous for its shepherd's crooks.

Ditchling Beacon, date uncertain. One of the highest points in East Sussex.

Prehistoric Cultivations, etc. 1000 B.C. to 500 A.D.

Thundersbarrow Hill, cultivations and village site, 1–400 A.D.

Truleigh Hill, west of the Dyke.

Eastwick Bottom, Patcham.

Buckland Bank, near Falmer.

Miscellaneous

Roman Villa remains discovered at Springfield Road, Brighton, and Southwick.

Ancient Tumuli, or burial mounds, are of frequent occurrence on the Downs near Brighton. Mostly between 2000 and 1000 B.C. Camping sites of the primitive inhabitants are numerous, and stone implements, including arrow heads, scrapers, knives, borers, etc., can be picked up in many places on the Downland.

Ancient Roads are to be seen at Eastwick and Park Bottoms, and can be traced elsewhere in the vicinity of the town.

Old village ponds, e.g., Falmer, Stanmer, Balmer.

Bronze Hoards have been found East of Black Rock and at Highdown Road, Hove, consisting of bronze axes, daggers, armlets and finger rings, etc.

Roman coins have been found in considerable number in Brighton and vicinity.

A Saxon Burial Ground Site was discovered near Port Hall Road, Brighton, in which were remains of Saxon warriors with their weapons.

MODERN METHODS OF COMPUTATION

At the Meeting of the British Association in Dundee in 1947, the subsection of Mathematics received a group of papers on modern methods of, and aids to, computation. The following notes are based on the material submitted.

General survey, by Dr. J. C. P. Miller

1. *Introductory.*

It is obvious that numerical calculations are necessary before a mathematical development may be said to have been applied fully to any physical problem. It is further becoming recognised more and more widely that such calculations should not always be avoided until they are inevitable or, in other words, that there are many cases where direct numerical attack is preferable to a clear and definite, though possibly tedious, mathematical treatment.

A more common attitude is that numerical work is tedious and a nuisance to be avoided at almost any cost. It thus seems worth while to emphasize that, to many, computing is a real pleasure, with its own problems and interests, and that a good numerical problem can easily be spoilt by unenterprising mathematics.

The need for numerical investigation is recognised also within the field of mathematics itself. Many mathematicians are not fully satisfied that they are thoroughly familiar with the properties of some special function, for example Bessel Functions, until they have seen tabular values and have made graphs or charts. This is particularly the case in the Theory of Numbers, where the numerical evidence nearly always comes first, and the explanation afterwards—sometimes centuries later.

The following notes give a bird's-eye view of various devices, methods and machines developed or adapted expressly for the easing of calculations. In the case of machines, adaptation of commercial machines has so far been most successful in producing results, and this process of adaptation has in recent years received great impetus from the efforts and ingenuities of Dr. L. J. Comrie, particularly in recognising the possibilities of the National Accounting machine. This machine, with its six intercommunicating adding mechanisms, brings into existence Babbage's dream of a differencing engine.

It may be, however, that the high-speed electronic machines such as the American ENIAC or the British ACE will eventually take the lead in output, but the development of such machines is still in its early stages.

The field to be surveyed may be divided up as follows :

(*a*) *Mathematical Aids to Calculation.* This includes, for example, the development of interpolation and finite difference formulae, and of the relaxation methods of Southwell.

(*b*) *Mathematical Tables.*

(*c*) *Calculating and Mathematical Machines.*

(i) Analogue machines, from graph paper to the differential analyser.

(ii) Digital machines, from the human hand and the abacus to ENIAC, ACE, etc.

These categories are wide, with ill-defined boundaries. For instance, the mathematical device needed in a particular case depends on the means available. Thus, for logarithmic computation formulae should consist largely of products ; for calculation with a machine, addition and subtraction are more convenient, though multiplication and division hardly less so.

2. *Mathematical Aids to Calculation.*

Mathematical methods are of very great importance. The first essential is always to develop a problem mathematically and to look for challenges to mathematical ingenuity. This needs a combined *mathematician-computer* who can appreciate computational difficulties often not apparent to many mathematicians. A complete reformulation of the problem may be the result of such an investigation.

Two kinds of mathematical aid may be distinguished :

(*a*) Special properties of the particular mathematical functions concerned. To find or develop these, it is usually wise to consult the best mathematician available, particularly if he has computational experience.

(*b*) General methods applicable to almost any function, such as interpolation by means of differences. The well-known *Interpolation and Allied Tables* by Comrie gives a useful collection of such methods.

It is important to remember that a properly designed computing form can make a tremendous difference to routine calculations. This is not only because it saves writing—one of the most time-consuming processes in computation and a fruitful source of errors—but because it improves neatness.

3. *Mathematical Tables.*

The choice of an appropriate table for a particular problem is of great importance. This century has seen rapid advances in the production of mathematical tables, but a surprisingly large amount remains to be done, even in fairly elementary fields. Two distinct trends may be noticed: (*a*) towards the production of adequate one or two volume *collections* of tables; (*b*) towards the extension of the field of tabulated higher mathematical functions.

(a) *Collections of Tables.*

(i) *Elementary Functions.*

Seven-decimal collections giving logarithms of numbers and of trigonometrical functions have been common for the last century. Five- and four-figure collections have become common more recently. This illustrates a tendency, still in progress, to produce collections with fewer figures. This tendency has a strong advocate in Comrie, who has done and is doing much to improve the standard of mathematical tables, as regards accuracy, appearance, usefulness and ease of use. Some standard collections are briefly described below.

Barlow's Tables. The first edition by Peter Barlow appeared in 1814. In 1840 A. De Morgan reduced them to (then) essentials and introduced the old style head-and-tail type, so important for legibility. Comrie's revised edition appeared in 1930. This has some additions, but has fewer figures in some cases. In 1941 an extended 270 page edition, also by Comrie, appeared. This is the volume, well known to most computers, giving squares, cubes, square roots, cube roots and reciprocals of numbers to 12500, values being either exact or to 7 or 8 figures.

Chambers's Tables. This century-old, 7-figure table giving logarithms of numbers, and logarithms and natural values of trigonometrical functions is well known. Many of the functions tabulated (mainly navigational) are obsolete, or of no use to the general computer. A new two-volume edition, by Comrie, is now in the Press.

The new volumes—one logarithmic and one giving natural values—will each contain 640 pages and will give only functions that are strictly mathematical, to 6-figure accuracy. The choice of six figures is made because this is the practical limit for a *collection* of tables covering a sufficiently wide range of function and argument, which may yet be linearly interpolable almost everywhere. All the elementary functions are tabulated as well as the gamma and probability functions.

Five-figure Tables. Various 5-figure tables have appeared from time to time. Those of F. Castle and J. B. Dale are well known. The latest to appear is by C. Attwood, *Practical Five-Figure Mathematical Tables.* This is to be in two parts of about 80 pages each. The first has just appeared and includes some innovations. The second part is to contain tables, such as hyperbolic and probability functions and elliptic integrals, that have only recently come to be included fairly consistently in general collections.

Four-figure Tables. The Standard Four-figure Mathematical Tables of L. M. Milne-Thomson and Comrie, with 260 pages, is the most extensive 4-figure collection of elementary functions. The latest tables to appear are *Chambers's Four-figure Mathematical Tables*, by Comrie. This 64-page table replaces the small table by C. G. Knott, and introduces many improvements, in material, presentation and in manner of use. At the same time the tables are arranged so that innovations in use may be ignored, and more familiar, though perhaps less accurate, methods used if desired. These tables will repay special study, and will encourage the interest of the keen user, since much attention has been given to explanatory notes. The table of F. Emde, *Tables of Elementary Functions*, with its emphasis on the solution of cubic and quartic equations and its sections on complex numbers, should also be noted.

(ii) *Higher Functions.*

Tables of Functions, by E. Jahnke and F. Emde. This is the pioneer table in this field. The first edition appeared in 1909, and new editions, both in Germany and U.S.A., have continued to appear since then. Some fairly elementary functions in earlier editions have become detached and are included in the Emde work previously mentioned. These are, however, still included in the latest American editions. The tables cover the whole field of tabulated mathematical functions, though few tables have been specially computed. The excellence of this project is such that one may forgive the large number of errors, due mainly to the policy of collecting existing tables without checking. The latest edition (Dover Publications, New York, 1945) incorporates over 400 corrections.

Three-figure Tables. The need for an even wider collection is increasingly apparent, and a set of 3-figure tables is being prepared by Comrie and Miller. This accuracy is adequate for most physicists and engineers, and allows the tabulation of a wide range of functions, interpolable linearly nearly everywhere, in a volume of reasonable size. The intention is, naturally, to use as much published material as is available, but to check all of it adequately, and to fill gaps by new

computations where necessary. Other functions, for which no obvious need is yet apparent, but which would almost certainly be welcomed if available, are also to be included.

Hayashi's Tables. The collections produced by K. Hayashi must also be mentioned. Although notorious for inaccuracy, they broke new ground when they first appeared, and are invaluable for computers—both for comparison with freshly computed tables, and for the training of computers in error hunting.

Peters and Stein. The 'Anhang,' by J. Peters and J. Stein, to the *Zehnstellige Logarithmen* of Peters contains a fascinating collection of many-figure values of constants, coefficients, logarithms, etc., of great interest to computers in particular.

(b) *Tables of Special Functions.*

This is a field in which the British Association, through its Mathematical Tables Committee, has played a major and pioneer part. The functions concerned are mainly higher functions, like Elliptic, Bessel or Mathieu functions, but tables like A. J. Thompson's *Logarithmetica Britannica*, a fundamental table giving 20-figure common logarithms, or 8- or 10-figure tables of trigonometrical functions of special merit, must not be overlooked.

In the elementary field one name is outstanding, that of J. Peters, who has given us, sometimes in collaboration, e.g. with J. Bauschinger or Comrie, the best special tables of logarithms and of trigonometrical functions in almost every case—6, 7, 8, 10 decimals, with arc in grades, in degrees and decimals, or in degrees, minutes and seconds.

The tabulation of special functions is a field that is developing very rapidly at present. Apart from individuals (such as W. S. Aldis), a British Association *Tables Committee*, forerunner of the present Committee, was first in the field. The first of a series of committees was set up in 1871 to report on mathematical tables, and resulted in the famous report of 1873 by J. W. L. Glaisher. Higher functions (Elliptic and Bessel functions) were soon taken up, and have engaged the attention of the Committee ever since.

Before 1930 four volumes of tables were produced under the Association's auspices: *Factor Tables for the 4th, 5th and 6th Millions*, by James Glaisher, and a *Binary Canon*, by A. J. C. Cunningham. Besides these, many small tables were published in the annual reports.

The present series of British Association Mathematical Tables was started in 1931 and has reached Vol. IX, with two smaller part-volumes, A and B. The existence of the Cunningham Bequest, for new tables in the Theory of Numbers, has led to the result that about half the volumes are connected with this field, as are other projected volumes. Other volumes that have appeared are:

Vol. I. Circular and Hyperbolic Functions, Exponential and Sine and Cosine Integrals, Factorial Function and Allied Functions, Hermitian Probability Functions.
Vol. II. Emden Functions.
Vol. VI. Bessel Functions, Part I.
Vol. VII. Probability Functions.
Pt.-Vol. A. Legendre Polynomials.
Pt.-Vol. B. The Airy Integral.

Of the "Cunningham" volumes, Vol. V, Factor Table, and Vol. IX, Table of Powers, are of wider interest than the rest.

For information on further volumes that are planned, the last report of the Committee may be consulted (*Advancement of Science*, No. 17, p. 67).

The National Bureau of Standards Computation Laboratory, formerly the Mathematical Tables Project of New York, with Dr. A. N. Lowan as its Technical Director, has played a great part in the production of special mathematical tables. Since 1939 a magnificent set of over 20 volumes of tables of special functions has appeared—all needed in a well-equipped computing laboratory.

The Harvard Computation Laboratory has produced eleven volumes to date—the result of the work of its IBM Automatic Sequence Controlled Calculator, with its 168 hour week. This is the first large scale modern computor to produce results that have appeared in book form. In particular seven of the thirteen large volumes that will eventually give the Bessel Functions $J_n(x)$ for $x = 0(0{\cdot}001 \text{ or } 0{\cdot}01)100$, $n = 0(1)100$, have already appeared.

4. *Observations on the Presentation of Mathematical Tables.*

(*a*) It is clear that the emphasis should be on the needs of the user—the table must be easy to consult and must not cause undue fatigue if used for long stretches. This may lead to much extra work on the part of the table-maker or compiler.

(*b*) It seems widely accepted that a table properly printed from type is preferable to one produced by photography from typescript.

(*c*) On the other hand, production by photographic methods from typescript is quicker, cheaper and needs much less work in checking. Such tables are, however, more fatiguing in use if much work is done—and there are usually more users than compilers!

(*d*) The publication of a typescript table may hinder the appearance of a better, printed table, by altering the market unfavourably.

(*e*) Proper attention should be paid to type and appearance, however a table is produced. In fact, the best possible results have not yet been attained by photography from typescript, since little or no attention seems to have been given to the design of suitable numerals for preparing typescript tabular material.

It has always been emphasized by the greatest acknowledged experts that old style numerals, with heads and tails, are the most easily legible ; yet equal-height numerals persist, especially on typewriters, but also in printed work.

(*f*) Numerals printed from type have a better ratio of breadth to height than have type-written figures. With the best printed figures, suitably spaced, it is possible to fit about twice as many numerical values to a page as with typed figures, with equal or superior legibility. Thus, with proper layout, a book printed from type may contain twice as much information for a given size.

(*g*) A book on tables should be compact. This point merits serious consideration. New tables continue to appear so that cost and, particularly, bookshelf-space are real problems. Most of the ' typescript ' tables that have appeared are twice or even three times as extensive as they would be if printed. This is very noticeable with the NBSCL (MTP) and Harvard volumes. It is often easier to use one or two compact volumes, even though interpolation may be a little more difficult, than three or perhaps more typescript volumes covering the same range of function and argument, though possibly at closer intervals.

(*h*) Interpolation must be catered for. Linear interpolation is clearly desirable, but is opposed to compactness, and a compromise must be reached.

The British Association Mathematical Tables, and the various tables by Comrie and by Peters, all of which are printed from type, have set a standard that has not been surpassed.

5. *Calculating and Mathematical Machines.*

(i) *Analogue Machines.*

This category includes all devices that replace a computational process by a physical analogue.

A simple example is provided by *graph papers*, which make use of the physical properties of lines drawn on paper by pencil, ruler and compass. These processes are often thought of as geometrical in Euclid's sense, but, in fact, the thickness of the pencil line and the physical limitations of paper and instruments cannot be ignored.

Further examples are afforded by *slide rules*, *planimeters*, *integraphs*. Bigger machines are the various *differential analysers* and the *Mallock machine* for solving simultaneous equations by means of the properties of electrical networks.

All analogue machines have their accuracy limited by physical considerations. This is often of no consequence and it can be even an advantage, as it prevents use of too many figures. However, their accuracy is often too limited, although such machines may provide extremely useful help when used with methods involving successive approximations.

(ii) *Digital Machines.*

The most familiar machines and devices belong to this class. The simplest are the human hand and the abacus. Digital machines are too numerous for a full catalogue to be given. Various types are here indicated, with notes on their capabilities and fields of usefulness.

Desk Machines.

These are mainly of two kinds, (*a*) adding machines, often recording items and results, (*b*) multiplying machines. They may be hand driven or electrical.

Each machine has its special particular capabilities, and the needs of the user will influence the choice of machine, whenever a choice is possible. When it is possible to have access to a fair collection of machines of various kinds, the best machine can be chosen for each particular piece of work. Choice of the right machine may easily halve the work. For general exploratory computational work, two machines seem outstanding to the writer—the Brunsviga 20 and the Facit LX. Both are hand machines. For routine work involving much multiplication, an electrical machine is most helpful. One of the best machines for general purposes is the Marchant ACT 10M. For statistical work, involving much evaluation of sums of squares, machines that can form squares from a single setting, such as the Monroe AA-1 or the Madas A24, are useful.

National Accounting Machine.

This, with its six adding mechanisms, which may be mutually interconnected, is an invaluable machine for table-making and table-checking. When cost and ease of operation are taken into consideration, it stands out as probably the most important machine for table-makers. It would be largely wasted, however, if a multiplying machine were not also available.

Hollerith and Punched Card Machines.

These represent a transitional stage between desk machines and the large scale automatic machines, involving individual units for special purposes (listing and adding, sorting, multiplying, etc.).

Large scale computors.

During the war, large scale computors developed rapidly. These include the Harvard IBM Automatic Sequence Controlled Tabulator, relay machines, and electronic machines such as ENIAC. The essential point about such machines is that they are capable of running for long periods without human intervention, once they have been set in motion.

6. *Summary of the Treatment of a Computing Problem.*

The various stages in the numerical treatment of a computing problem or in tabulating a mathematical function may be summarised as follows :

(1) Mathematical investigation by a Physicist-Mathematician.

(2) Adaptation to Computation by a Mathematician-Computer.

(3) Computation. With desk machines, one may just go ahead ; with large-scale machines, the machine must first be prepared for the problem, at present a fairly long process.

(4) Use of results. The results needed may be a few numerical quantities resulting from long computational chains, or a table of many values that requires publication for effective use.

7. *General Remarks on Calculating Machines.*

Large scale computors have a great future, but there seems to be no reason why they should supplant present methods : it seems more probable that their advent will increase the demand for human computers, for mathematical tables, and for desk machines.

The human computers will be needed to tell the large machines (which can only obey instructions) what to do and how to do it. The desk machines will be needed by the human computers to prepare material for the large machines and, a matter of utmost importance, for the *training* of computers.

The mathematical tables will be needed as auxiliary memories for the large machines, just as they are needed in that capacity to aid human memories. A machine may be designed to have a memory of perhaps 30,000 numbers ; a small book of tables, like Barlow's tables, has a memory of over 75,000 eight-figure numbers. There is a tendency at present to give a machine an auxiliary memory on punched cards, but this appears to be a transitional stage—the machine will be taught to read !

At present, with electronic speeds, computation is fast, so fast that the necessary time is entirely negligible. It seems probable that future developments will reduce the time needed to prepare the machine for the problem and to record the results.

It therefore seems desirable to reserve large-scale (and particularly electronic) machines for problems that need an enormous amount of computation for perhaps only two or three results worthy of record. Such problems will then become possible, and there are very many of them. In the meantime, more familiar machines and methods will still be needed for the many problems of simpler nature, with a larger proportion of results worth recording, and for making tables to act as memories for the large machines, and for use by human computers.

Description of modern large-scale calculating machines, by Mr. J. R. Womersley (who was unable to be present to read his paper).

It is convenient to distinguish two main classes of calculating machines. The first consists of those machines which represent numbers by physical quantities of which the numbers are the measures. Simple examples of this type are the slide rule and planimeter ; a more sophisticated example is the Differential Analyser. All ' analogue ' machines, as machines of this class are called, are limited to the accuracy of a physical measurement. The second class of machines consists of those which handle numbers directly in their digital form ; examples of this class are the standard desk calculating machines such as the Brunsviga and Frieden and the punched card machines such as Powers, Hollerith or I.B.M. equipment.

The most promising of recent developments in the field of calculating machines has been in the class of digital machines designed to carry out automatically extended sequences of computing operations which may be changed from one problem to another. The idea of a general purpose automatic computing machine is due to Charles Babbage (1840). He attempted to design a machine capable of carrying out, not merely single arithmetic operations, but whole series of operations, without the intervention of an operator. Any such machine must have, in addition to the equipment needed for the fundamental operations of arithmetic, addition, multiplication and division, a method of storing intermediate values obtained in a computation, and also a method for storing the operating instructions. There must also be some means of communicating with the

outside world, both for the purpose of receiving the instructions and the initial data for a problem and for transmitting the final results.

The ' analytic engine ' conceived by Babbage has been very closely realised in the I.B.M. Automatic Sequence Controlled Calculator completed at Harvard in 1944. It consists of an assembly of I.B.M. components which have been interconnected to form a calculating machine, capable of attacking a very wide range of problems. The machine is equipped with 72 adding and storage units and 60 other units which can store numbers but do not possess the adding facility. There are also units which multiply and divide and units for performing interpolation in a given table. The results may be printed by automatic typewriters or stored on punched cards. The sequencing of the machine is controlled by sets of timed electrical pulses which are derived from coded instructions punched on paper tape. This tape is fed past a set of electrical contacts which sense the holes in the tape and by this means convey appropriate instructions to the components. Before a problem can be put on the machine the appropriate instructions must be worked out, coded and then punched on the tape. The times taken by the machine for the standard arithmetical operations are not very remarkable ; addition takes about one third of a second, multiplication about six seconds and division twelve seconds. These figures are for twenty-three digit decimal numbers and, of course, cover the time taken to compute a value and ' write it down.' Since, however, the machine can keep up this pace continuously its achievements are quite considerable.

The only machine yet completed which makes use of the technique of electronic circuits to achieve a high speed of operation is the Electronic Numerical Integrator and Calculator, usually called the ENIAC, built by the Moore School of Electrical Engineering of Pennsylvania. This machine operates by counting electrical pulses, produced at a frequency of 100,000 per second, by means of electrical counting circuits. It consists essentially of a number of units for addition, multiplication, division, storage and control which can be interconnected by being pluggd into sets of transmission lines. The sequencing of its operations is determined by the setting of a number of switches, which results in the appropriate interconnections. The input and output mechanisms are both ' punched card ' equipment. The machine was originally designed for the numerical integration of the equations of external ballistics, but it is sufficiently flexible to be applied to quite a wide range of problems. Its speed of operation is of a different order from that attained on any other machine in existence ; some idea of this speed can be formed from the fact that it can add 2 ten-digit decimal numbers in about one five-thousandth of a second and multiply two such numbers together in less than three-thousandths of a second.

Although the ENIAC is quite satisfactory in respect of speed, it falls far short of the requirements of many problems of mathematical physics in its storage capacity. Any machine which performs the elementary operations of arithmetic at a speed comparable with the ENIAC must be able to store numbers, obtained at an intermediate stage, in a form in which they can be called upon by the machine in a time comparable with its speed of operation. Otherwise its speed would be largely dissipated. Now in spite of the fact that the ENIAC contained about 18,000 electronic valves and 1500 relays, its high speed storage capacity was about 20 ten-digit numbers only. If more numbers than this had to be remembered at any one time, some of them had to be stored on punched cards and ' called for later ' ; this slowed up the operation of the machine enormously. Many of the problems which are of great importance require the storage of several thousand numbers at intermediate stages, so a solution of the storage problem for such computations on the lines of the ENIAC is out of the question.

In the Automatic Computing Engine which is being designed at the National Physical Laboratory we expect to have the solution to this problem. In this machine our numbers will be stored in the binary system in a number of units known as acoustic delay lines. The reason for the use of the binary system instead of the decimal system is because, in the binary system, each number consists of a sequence of zeros and ones and therefore admits of a simple representation as a pattern of electrical impulses. Each of our delay lines will be capable of storing the equivalent of about 32 nine-digit decimal numbers. Unlike the ENIAC, the sequencing of the operations in the A.C.E. will be performed by means of coded instructions which will be stored inside the machine in the delay lines, in exactly the same manner as the numbers themselves. The input and output mechanisms of the A.C.E. will probably be ' punched card ' equipment, at any rate in the first model. The operation of coding a problem for A.C.E. will be somewhat similar to that of coding for the Harvard machine, but since the instructions will be stored in the high speed memory the speed at which they will be carried out will be far higher. With its high speed of operation and its large storage capacity the A.C.E. will be able to undertake problems which have so far been regarded as insoluble

because of the prodigious amount of computation they involve.

Principles of programming on large-scale calculating machines, by Mr. J. H. Wilkinson

An important stage in the development of digital computing machines was the application of electronic circuits to speed up the rate of computation. The only machine so far completed which does this is the ENIAC. It consists essentially of a number of units for storage, control, addition, multiplication and division, which may be interconnected by means of switches ; the sequence of operations is determined by these interconnections. Initial data is fed in from punched cards and the final results are fed out in the same form. The ENIAC achieved far greater speeds than those realised hitherto ; multiplication of 2 ten-digit numbers, for instance, took only $2\frac{1}{2}$ milliseconds. The limiting factor on its flexibility was its small 'high-speed' storage capacity, which was limited to 200 decimal digits. The storage capacity was adequate for the integration of ordinary differential equations, but fell far short of that required for the solution of partial differential equations and other problems in which it is necessary to store a two dimensional grid of numbers.

In the machines which are now being planned at the N.P.L. and in the U.S.A. the limitation on the storage capacity has been overcome ; the increase in storage capacity has necessitated a fundamental change in the method of control. Instead of being controlled by the pre-setting of a number of switches, the operations are sequenced by a set of coded instructions which are stored by the memory in the same way as the numbers. This has extended enormously the range of problems which can be efficiently undertaken by the machines.

An electronic differential analyser, by Dr. J. M. Jackson

The use of a small scale differential analyser is frequently of service in technological work where a rapid survey of a particular field is required. Such an instrument of an accuracy of about 5 per cent. can be made from standard radio equipment and Post Office components for a reasonable cost of about £150.

The principle involved is the artificial lengthening of the time of charging a condenser by the use of feedback. This enables the instrument to integrate up to 10 minutes and it can be used for the solution of second order differential equations.

The present situation with regard to the large scale differential analysers in this country and in the United States is that they are booked up with orders for years ahead, so that the use of the instrument described above enables some knowledge of the problem to be obtained without waiting for a long time.

Relaxation methods, by Dr. L. Fox

The method of relaxation is now an essential part of the equipment of the first-class computer. First presented at the British Association meeting in 1936, it has in the last ten years been applied to many problems covering a wide field in engineering, mathematical physics, and even pure mathematics.

Its essential feature is a method of successive approximation for the solution of simultaneous equations. The latter may arise in several ways, the most important being obtained from the replacement of derivatives by finite-difference expressions. By this means many important problems requiring the solution of differential equations of the closed boundary type, such as Laplace's equation

$$\nabla^2\phi = 0$$

or the biharmonic equation

$$\nabla^4\phi = 0$$

can be successfully tackled.

With the assistance of Rayleigh's principle, problems of free vibration of engineering structures such as aircraft engines and wings, as well as the vibration of membranes and the buckling of plates, come within its scope.

The method in practice is performed by calculating the errors of a trial solution and reducing them to negligible amounts by intelligent changes in the components of this trial solution. The process is not rigidly bound by fixed rules, but leaves much to the intelligence, judgment and skill of the operator computer.

With its tentative approach, relaxation methods can succeed in problems which are quite intractable by orthodox mathematics.

Fourier Transformer.

Professor Max Born, F.R.S., gave a description of his machine for exhibiting directly, on a Cathode ray oscillograph, the Fourier transform of a given function.

BIOCHEMICAL APPLICATIONS OF STABLE AND RADIOACTIVE ISOTOPES

By Dr. A. S. McFarlane

With but one exception the body makes no discrimination whatever between natural elements and their stable or radioactive isotopes. In addition, the stable isotopes with the exception of deuterium, have no deleterious effects on living cells even in the highest concentrations. In the case of the radioactive ones it is always possible to employ such low concentrations that, in most cases, human experiments can be carried out with safety, and in all cases animal ones with impunity since genetic effects of the radiations can be ignored. These simple considerations have made possible to the biochemist a new kind of experimental approach which he has not been slow to make use of.

One of the earliest isotopes to become available was radioactive phosphorus (P^{32}) and of course it was administered as sodium phosphate by various routes to animals and its excretion observed and an analysis made of the skeleton and various organs to determine where and for how long it was retained. It was soon established that only a small fraction—less than 10 per cent.—is excreted in 24 hours and of the total amount injected only a few per cent. is present in the lymph and plasma a few hours after injection. The remainder has disappeared into the cells of the body, especially of the skeleton, the liver and the intestine.

Precisely how this phosphorus is taken up by the cells is a matter of some general importance. By whatever route it is injected a high concentration of P^{32} occurs within a few minutes in the lymph and plasma. From the lymph the cells take up phosphate at a steady rate and discharge it back at the same rate into the same medium. There is no discrimination between ingoing and outgoing phosphate and complete mixing takes place within the cell. The process consists in fact of a continuous diffusion in both directions across the cell wall, radioactive phosphate passing out of the cell long before all the inactive phosphate in the cell has been replaced. If the concentration of radioactive phosphate in the lymph is kept constant—and there are several experimental tricks for doing this—the conditions are simplified and it can be shown that the mean specific radioactivity of the phosphate in the cell rises exponentially with time. Since the exponential curve is almost linear in the first part of its course a simple measurement of the specific activity of cellular phosphate after a time interval which is short in relation to the time required to replace all the phosphate is sufficient to determine the steady rate of exchange of phosphate in the cell. For example after 4 hours the activity of the phosphorus in the tibia of a rat is one six-hundredth that of the phosphate maintained constant in the lymph and we may conclude that in 4 weeks an amount of phosphorus passes into and out of this bone equal to the total weight of phosphorus in it. This is called the replacement or turnover time. In a few cases where the turnover time is short it is possible to make allowances for the non-linearity of the growth curve and to obtain exact turnover values but in general this is not possible and the results obtained by assuming linearity are known to be of the right order only. However, to know the larger turnover times accurately and the shorter ones approximately, has proved nevertheless to be a matter of great importance to our understanding of the chemistry of the body.

The phosphorus taken up by the skeleton is laid down for the most part in inorganic form but elsewhere in the body it is incorporated into a large and still expanding group of complicated organic compounds. Outstanding among these are the phospholipids which are present in the blood plasma and in all cells. By transfusing radioactive plasma phospholipids to a dog and observing their rate of disappearance from the recipient's plasma it is shown that the plasma phospholipids are completely replaced in 6 to 10 hours. The liver is the main site of synthesis and degradation of these substances since removal of the liver prolongs the turnover time to 33–160 hours. Removal of the intestine on the other hand has no effect. Although the liver produces enough phospholipids to renew the plasma reservoir inside 10 hours it requires 50 hours to renew its own phospholipids. The intestine renews its phospholipids in 40 hours, but the brain which is rich in these substances requires 4 weeks for their replacement.

Another important phosphorus compound of the body is nucleic acid of which two main types are present—one characteristic of the nuclei and the other found in high proportion in the cytoplasm of all cells. The P in the nuclear form is exchanged very slowly—about the same as in bone—but in the cytoplasmic form it is exchanged 10 times as quickly. That is the position in normal adult cells but when the cells are dividing, e.g. in embryonic tissues, in regenerating tissues or in malignant growths the position is vastly changed, the nuclear P exchange increasing 10 to 15 times. This confirms and establishes on a quantitative basis general impressions derived from the histology of the tissues but the tracer method can go further than this. It can distinguish the rate at which nucleic acid P^{32} builds up inside a cell from that at which it disappears. In this way—and in no other—it can be shown that growth from any of the causes mentioned results not from an increased rate of synthesis of cell compounds but from a diminished rate of disintegration so that when the organism reaches maturity it is because it has been able to accelerate its intracellular breakdown processes until they are as rapid as the synthetic ones.

It is clear also in all these studies that some injected phosphorus is excreted into the lower bowel and it can easily be demonstrated that part of the phosphorus of our diet which is absorbed in the upper alimentary canal is re-excreted and mixed with unabsorbed phosphorus in the lower. This could not have been demonstrated by any other method. An entirely different picture comes to light if this experiment is repeated using radioactive iron in the diet. Hahn and Whipple have shown that in a normal adult practically all the iron passes through the gut unabsorbed but if the subject has been made anaemic new radio-iron is absorbed into the circulation. The new red cells which are produced differ from the old ones in having some of this radio-iron incorporated in the hæmoglobin molecule. These radioactive cells persist in the circulation for some months as do all red cells and are finally destroyed in the spleen and liver where their iron is stored. In time this iron finds its way back into the circulation for incorporation into new red cells. Here once again the tracer element is able to reveal something which could not have been discovered in any other way, viz. that the body is extremely conservative in relation to this particular constituent of the diet endeavouring as far as possible to carry with it enough iron circulating internally to meet all its requirements. It is as conservative in relation to iron as it is liberal in relation to phosphorus and no doubt the difference is due to the wider distribution of phosphorus in nature. The mechanism by which the intestinal mucosa ' senses ' internal iron deficiency and responds by allowing some of the element to pass from the gut into the blood is not yet understood but its beauty is impressive.

A few days after administering the amino-acid glycine containing C^{13} in the methyl group and N^{15} in the amino group to rats the isotopes are found in adjacent positions in the protoporphyrin of hæmoglobin. This tells us much about the manner in which the body synthesizes the 5-membered pyrrol ring and at the same time provides a convenient method of labelling the red cells of the blood. If N-labelled glycine is given to a human being the isotope is detectable in the red cells at the fourth day and the concentration rises steadily over a period of 25 days, remaining constant for a further 50 days and dropping slowly to zero in the next 150 days. Rittenberg and Shemin who first observed this behaviour were quick to note its unusual character. Normally when a tracer is injected the concentration of labelled compound in a tissue or organ rises to a maximum as synthesis proceeds and immediately thereafter declines again as the labelled molecules are metabolised. The 50-day period of constant isotopic porphyrin concentration can only be explained in one way. The porphyrin of the newly-formed red cell is excluded from the metabolic reactions of the body and only enters into these again at the end of the life span of the red cell. Statistical analysis of the results shows that the average life of a human red cell is 127 days. This method is not the only one leading to this result but is particularly elegant in involving no more disturbance to the subject than is associated with feeding labelled glycine. The method further reveals that when the red cell finally disintegrates the porphyrin group, unlike iron, is not further utilised in the formation of new red cells.

The body contains three important substances, choline, creatine and methionine with no obvious chemical structural relationship to each other except that each has a methyl group linked to the rest of the molecule through sulphur or nitrogen. Deficiency symptoms due to the absence of choline from the diet can be cured by giving methionine and the absence of both choline and methionine from the diet affects the excretion of creatine as creatinine. There is clearly, therefore, a metabolic interdependence between these three substances and a clue to its character is found by administering one of them with deuterium in the methyl group. The isotope is subsequently found in the methyl groups of the other two and nowhere else. It seems that a methyl group linked in this way is handled by the body quite differ-

ently from a methyl group linked through carbon. We are introduced here to the idea of a vitamin-like importance in the diet of a particular radical. In not dissimilar fashion the amino groups of all the amino-acids of the diet are merged in a metabolic pool from which the amino-acids of the tissues are derived. This is shown by administering N-labelled glycine or ammonia and finding the isotope in all the amino-acids except lysine of the tissue proteins.

If carbon dioxide containing isotopic carbon is breathed in it is found that some of the carbon finds its way into glycogen in the liver and from there to other compounds of the body, thus disposing in one simple experiment of the belief that only plants and bacteria can utilise carbon in the form of carbon dioxide. Needless to say biochemists in the last few years have investigated this phenomenon intensively and no less than six distinctive chemical reactions are now known by which the body can fix carbon dioxide, the most important one being the condensation of carbon dioxide with pyruvic acid to give oxalo-acetic acid.

Arising out of this and other experiments much attention has been paid in recent years to acetic acid. In the past this has been little investigated because acetate is known to be present in insignificant quantities in the body and these are extremely difficult to measure precisely. With the advent of isotopes, however, an inefficient method of isolation may be made the basis of a precise method of estimation as the following example will show. Supposing a compound containing C^{13} is given in the diet and we wish to know whether any part of this C^{13} is incorporated into acetate in the liver. A known weight of liver is mixed thoroughly with a known but excessive weight of normal acetate and the mixture is fractionated to recover a proportion of the acetate. At the same time the same proportion of labelled acetate is recovered—minute in amount but sufficient for mass spectrometric estimation. Multiplication of the result by the recovery factor tells us the weight of labelled acetate in the piece of liver. This has become an important general method of analysis known as the isotope dilution method.

When a fatty acid labelled in the carboxyl carbon is oxidised by the liver some acetate—but considerably more acetoacetate—is found. This acetoacetate is labelled in both carbonyl and carboxyl groups indicating that it is formed by condensation of acetyl groups, methyl to carboxyl. Acetoacetate is not further utilised by the liver but is oxidised elsewhere. The kidney among other organs can oxidise it and is known also to take up acetate but normally no acetoacetate can be found in it. By incubating kidney slices with labelled acetate in the presence of an excess of normal acetoacetate and demonstrating the presence of isotopic acetoacetate in the excess recovered it is shown that the oxidation of acetate is in fact through acetoacetate but the latter is normally further oxidised as soon as it is formed.

An alternative tracer procedure to the above has been to feed labelled acetate and to investigate the more complicated molecules of the body to find what has happened to that part of it not immediately excreted. By this procedure the carbon skeleton of acetate has been identified in the dicarboxylic amino-acids of the tissue proteins, in the fatty acids of the liver and depot fats, in cholesterol and in glycogen. It has been shown that although the carcass of a 100 gm. rat contains but a few milligrams of acetate, more than a gram of acetate is produced in its liver every day.

These developments, which are largely, if not exclusively, derived from isotope studies, represent substantial contributions to biochemistry. They reveal numerous unsuspected metabolic pathways and if some of these are but little used normally, as for example the fixation of CO_2, they may be of the greatest importance in disturbed metabolic states, e.g. in diabetes where acetoacetate and related ketone bodies are produced in abnormal amounts. They demonstrate that the amount of a substance present in a tissue bears little if any relation to its metabolic importance, and that important intermediary metabolites may not even be present in detectable concentrations. They focus attention on turnover rates rather than on concentrations, thereby heralding a new dynamic viewpoint in which the body is conceived as in a state of incessant change, atoms and molecules displacing one another with surprising rapidity in every tissue. All that remains constant is the pattern into and out of which these atoms pass—a stereochemical relationship of atoms within molecules, and a spatial juxtaposition of molecules within tissues—which is specific for each individual and characteristic of living matter as a whole.—*Paper read at a joint meeting of the Chemistry and Physiology Sections of the British Association at Dundee on September* 2, 1947.

INSECTICIDES

Report of a Discussion

One of the greatest problems in the world to-day is the provision of food, yet plans for increasing the acreage under cultivation, for improving agricultural technique throughout the world, and for distributing agricultural produce where it is most needed may be vitiated by losses due to insect pests. It has been estimated that some five per cent. of the world's food production is lost in this way and in some crops, such as maize, for example, the loss may range from 10 to 30 per cent. in certain food producing areas. Control of insect food pests is therefore a matter of extreme importance : and of no less importance is the control of disease-bearing insects which so seriously affect the health of man and beast, particularly in tropical countries. The significance of the contribution which insecticides can make to human progress was acknowledged in drafting the programme for the meeting of the British Association in Dundee, and the Sections of Chemistry, Zoology and Agriculture arranged a joint session under the chairmanship of Dr. J. L. Simonsen, F.R.S., at which recent knowledge of insecticides was reviewed and discussed. The following is a record of the main papers.

Insecticides in Agriculture

By C. T. Gimingham, O.B.E.

The urgent need for maximum production of food during the war and since has led to a much more general realization of the importance of insect pests in agriculture and horticulture than was formerly the case. The serious losses for which they may be responsible and the necessity of taking all possible measures to reduce such losses to a minimum are recognized and accepted.

It is a commonplace to point out that, under natural conditions, there is normally a kind of balance or equilibrium established between phytophagous insects and their enemies and the plants that they feed on, and that disturbances are temporary and brief. When, however, man interferes and grows large areas of single kinds of plants in cultivation, conditions are created which favour the insects that feed on those particular plants. While it is true that, even under these conditions, a balance between the phytophagous insects and their enemies (parasites and predators) tends eventually to be set up, the effects of fluctuations in their relative numbers are much more marked and it is rarely safe to rely entirely on natural enemies for a sufficient degree of protection where maximum yields and high quality of produce are the aim.

One type of control measure for particular pests is the artificial introduction of certain parasites or predators into new areas and this has, in a number of instances, led to practical results of great value. At present, however, it is only under somewhat exceptional circumstances that biological control methods of this kind appear to be applicable, but their usefulness will surely be greatly extended.

Also of the greatest importance are measures which help the crop at a critical period to escape from attack by insect pests or at least to avoid the worst effects of attack. In particular instances, losses may be greatly reduced by the application of fertilisers at the appropriate time, or by special cultivations, or by alteration of the date of sowing or planting, or the growing of specially early or late varieties of crop plants, or the adoption of special rotations. Such measures are generally referred to as cultural control methods.

The breeding of varieties of crop plants resistant to infestation by the insects that feed upon them is a more long-term project. The production by plant-breeders of new varieties with high resistance or immunity to attack as well as high yield and quality, if it can be done, is much to be desired, and considerable progress has, for example, been made at Oxford in breeding varieties of oats resistant to attack by Frit fly, and work in Germany gives promise of success in the production of potatoes resistant to the Colorado beetle. The possibility that the pests themselves will take a hand in this and eventually produce strains capable of attacking resistant varieties cannot, however, be excluded.

Biological and cultural means of dealing with the problems of insect control, such as those just mentioned, are of the utmost importance and value, but, in addition, a direct attack on the pests, aimed at their immediate destruction is forced upon us if crops are to be adequately protected. For this purpose insecticides used on a very large

scale indeed, in the form of sprays, dusts, poison baits, and fumigants, unquestionably provide the main line of defence.

Long experience has demonstrated the very important rôle that insecticides, properly used, play in the control of insect pests and consequently in food production. Obviously, however, their use must be considered in relation to the value of the crop, and this is reflected in the fact that at present they are more widely employed in horticulture and fruit-growing than on purely agricultural crops. Suitable machinery for the application of insecticides is lacking on the average farm, but in recent years there has been an increase in the spraying or dusting by contract, by firms specializing in work of this kind, of such crops as sugar-beet, potatoes, brussels sprouts and other brassicae, peas and carrots grown on a field scale. It may be that the future of the use of insecticides in agriculture, as distinct from horticulture, will be along these lines.

Among the most important pests of agricultural crops are wireworms, leatherjackets and other insects that live in the soil, and in spite of much work on the subject, there has been a notable lack of any really satisfactory soil insecticide. It looks as though this long-felt want may now be remedied, for in the past year or two very promising results have been obtained in protecting cereal and other crops from attack by wireworms by the use of insecticides containing benzene hexachloride drilled with the seed. Further experience with this material as a means of dealing with soil pests is awaited with special interest.

Among the materials most widely used as insecticides in Britain are nicotine, derris root, pyrethrum flowers, arsenical compounds, tar oil and petroleum oil preparations, calomel and the new synthetic organic compounds dichlorodiphenyl trichloroethane (D.D.T.) and hexachloro-cyclo-benzene, more generally known here as benzene hexachloride. Each one of these has it special purpose.

Throughout the history of the efforts to control insect pests of plants by the application of chemicals, the main problem has been to find materials with sufficiently effective insecticidal properties but harmless to the crops and to the consumer, whether man or domestic animals. These problems are still with us and attract much more general attention and interest than in the past, partly because of the greatly increased realization of the importance of insect pests of cultivated plants (almost everybody now being a farmer or gardener in greater or less degree) and partly because of the discovery in recent years of new synthetic organic insecticides of exceptional potency. Insect pests and means for their control now being ' neew,' information about these new insecticides—not all of it accurate—has received widespread publicity, a publicity somewhat embarrassing to those whose business it is to try to advise on pest control. Formerly there was time to learn by experience and by experiment the proper uses of an insecticide and a considerable body of knowledge has accumulated, which can be applied in practice, about all the older and well-known materials. With the changed situation, however, some of the newer insecticides have been made available before there has been time to explore their potentialities fully enough to discover accurately their proper uses and limitations for agricultural and horticultural purposes and the adviser is bombarded with queries to which he can give only tentative answers. Much has been done to remedy this, and reliable information is rapidly being collected, but in the nature of things agricultural experiments take time. I refer to this because it explains to some extent why controversy has arisen with regard to the use of the new insecticides in a way that did not occur when the older insecticides were introduced though much the same problems were presented.

Among these, one that may be of general interest and relevancy is the effect of the application of insecticides to plants upon the insect fauna as a whole. In using insecticides in practice, the aim is not the indiscriminate destruction of all kinds of insects, for those species that are injurious to cultivated crops are comparatively few and among the vast number of other species there are many that are actively beneficial from man's point of view.

It is essential to reduce to the minimum the risk of destroying bees and other pollinating insects, and also the parasites and predators that help to keep the pests in check. Experience with the older insecticides made this clear enough. For example, lead arsenate used for the control of important pests of fruit, if wrongly applied, may cause serious losses among bees, though by avoidance of spraying open blossom this can be prevented. Again, the routine use of tar oil washes for winter spraying of fruit trees appears almost certainly to be connected with the great increase in the importance as a pest of the mite *Oligonychus ulmi* known as the Fruit Tree Red Spider. These washes, introduced some twenty-five years ago for the control of aphides and other pests by destruction of their eggs, also clean the trees of moss and lichens. Before their introduction, the Red Spider was little known as a fruit tree pest, and it appears that its numbers were kept at a low level by the activity of certain species

of predatory bugs that feed on the mite and its eggs. The destruction of the shelter needed by these insects has led to a decrease in their numbers, with the result that Fruit Tree Red Spider, the eggs of which are not killed by tar oil washes, has become a much more troublesome pest, requiring other measures for its control.

Obviously, examples of this kind from past experience emphasize the need for careful study of the effects upon the insect complex as a whole of the use in practice of new and powerful synthetic insecticides such as D.D.T. and benzene hexachloride. Some of these materials present special problems since, unlike most of the older insecticides, they act both as internal poisons when ingested by insects and also externally as contact poisons ; moreover, some are more persistent, remaining toxic to insects on treated surfaces for a considerable time after application, a property that has come to be known as the ' residual effect.'

The investigation of the problems presented by the introduction of a new insecticide is not a simple matter ; it cannot be completed quickly in the laboratory alone, for field observations over a number of seasons are necessary. For instance, to quote from a Canadian report : ' a long-term investigation has been started in Nova Scotia to study the cumulative effects which the annual application of various spray materials have on the natural enemies of apple insects and to determine which insecticides and fungicides are most and which are least detrimental to biological control.' The materials used in this series of experiments has not so far included the newer insecticides, but similar studies are in hand in this country and in the United States with insecticides containing D.D.T. The proper uses and limitations as agricultural insecticides of D.D.T. and benzene hexachloride have in fact been intensively investigated in the few years since they became generally available, though there is still much to be learned about them. With some of the other new synthetics (Velsicol 1068, toxaphene, hexaethyltetraphosphate) our knowledge of their practical possibilities is still at an early stage.

It may be of interest briefly to summarise the position reached with D.D.T. It is certain that D.D.T. is highly effective under practical conditions for control of many agricultural and horticultural pests, and, although possessing poisonous properties, the verdict of toxicologists is that D.D.T. insecticides, as normally applied with ordinary precautions of a kind familiar to users of insecticides, are harmless to human beings and livestock, and may be used without appreciable danger of risk to health. Further, experience has shown that, with minor exceptions, no damage is caused to crops treated. As with other insecticidal compounds, D.D.T. is toxic to a wide range of insects, but it is not equally toxic to all ; some species are resistant to its action, others susceptible. It is possible on the basis of present information to list a considerable number of pests (e.g., Flea Beetle, Colorado Beetle, Cabbage Butterfly Caterpillars, Apple Blossom Weevil) for which D.D.T. insecticides are an effective means of control, others for which they are promising or about which no certain answer can yet be given, and others for which they do not appear to be effective (e.g., Cabbage Aphis, Red Spider). It should, however, be emphasized, that such conclusions may have to be modified as the results of further work become available and improved methods of compounding D.D.T. preparations may well be discovered which will extend its range of usefulness. As to the effect upon beneficial insects, while there is much work to be done, it has been found by experiment that bees are fortunately fairly resistant and that sprays and dusts containing D.D.T., as used in practice, are almost harmless to them. On the other hand, many useful parasites and predators are readily killed by D.D.T. insecticides, and though available evidence indicates that, as with other insecticides, the effect is temporary and the balance is quickly restored, in particular instances this is of special importance. For example, Codling moth (*Cydia pomonella*) on apples is one of the pests that can be well controlled by D.D.T., but experience both here and in America has shown that its use against this insect may lead to a serious increase in Fruit Tree Red Spider because D.D.T. does not destroy Red Spider but does kill predatory insects that otherwise help to keep it in check. Consequently D.D.T. insecticides should not, in the present state of our knowledge, be used for control of Codling moth.

The example just quoted is an instance of what has come to be known as the selective action of an insecticide, and in this case operates to our disadvantage. The ideal solution of the problem would be the discovery of materials so selective in action that they would discriminate between the pest insects and their enemies, and destroy only the pests. This is no doubt too much to ask at present, but the very marked differences in susceptibility shown by different species of insects and mites to the action of insecticidal compounds, do provide a starting point for investigation. Attention has recently been drawn to an instance in which the selective action of one of the best-known insecticides—nicotine—is in fact utilised to advantage. For the control of the Cabbage Aphis, often a

serious pest of brassica crops, nicotine vaporized under a drag sheet, is applied on a field scale by means of special machines. A very high percentage kill of the aphides is obtained by this method, and it is found that predatory Coccinellids and Syrphids and an abundant Braconid parasite of the aphis are little affected and remain to continue the destruction of the aphides which survive the treatment, a desirable combination of chemical and biological control.

It is bound to take some time to find out in full detail how to use the new and powerful insecticides now in our hands to the best advantage and with the greatest gain to food production, but their discovery, and the prospect of more to come, hold out immense possibilities of increased control of the insect enemies of our crops.

The Place of Insecticides in Food Protection

By Prof. J. W. Munro

While much can be achieved in the protection of foodstuffs from insect attack by cleanliness and other hygienic measures in the warehouses, such measures are periodically found to be inadequate and, particularly since the war, the use of insecticides has become unavoidable. While in agriculture the risk of damage to the plant is an important factor, in the use of insecticides in protecting foodstuffs the risk of tainting or even of the poisoning of the food is of paramount importance. This is particularly true of foodstuffs which are not ' processed ' before reaching their consumer and it severely restricts the number of insecticidal materials permissible in this field of work.

There are two problems to be dealt with in the protection of foodstuffs. The first is to protect the food commodities themselves and the second is to ensure that the premises in which they are housed and the vehicles in which they are transported are not allowed to harbour or maintain a similar insect population. Apart from the use of certain sprays in warehouses and on ships and other forms of transport, fumigation is practised in commerce much more widely than in agriculture and raises special problems. The most important of these is the effective distribution of the fumigant, gas or vapour in the chamber, warehouse or barge. Faulty distribution may fail to kill the insects and may also result in an unduly high residue of fumigant being left in the commodity, which may seriously taint it or even cause it to be unfit for animal or human consumption.

(Professor Munro briefly described the research done and the results achieved in these fields.)

Experiments with Aircraft in the Control of Locusts and other Insects

By Dr. J. L. Gunn

The recent development of potent contact insecticides makes possible effective use in very low area dosages. For example, in anti-mosquito aircraft spraying experiments in East Africa, for practically complete kill the dosage applied was 4½ pints of 5 per cent. solution of D.D.T. or 4·5 ozs. D.D.T. per acre, i.e. 30 mg./m.^{2}. Under ideal conditions, there is reason to believe that 5 mg./m.^{2} would give 100 per cent. kill. Under ideal conditions a similar weight (4 ozs.) of D.N.O.C. per acre would be 100 per cent. effective against locusts.

In order to take advantage of this potency, new methods are required to ensure sufficiently uniform distribution of the poison over the treated area. One way of ensuring that the dosage is adequate and even is to use a very large volume of weak solution and keep on spraying until the liquid runs off. In orchards, this may require hundreds of gallons per acre.

But the use of large amounts of diluent which may have to be carried long distances is often too costly and difficult. In Africa there are many situations where even water is not readily obtainable in large quantities, and the carriage of large quantities of any diluent long distances is to be avoided.

On the other hand, it is sometimes not feasible to apply undiluted insecticide sufficiently evenly. Consider the case of a liquid which is lethal at 4 oz./acre. To get one drop per square centimetre, the drops would have to be only 0·17 mm. in diameter. If the target insect is only 1 mm.^{2} in area, many of the insects would not be touched by poison at all, while a few would get an overwhelming dose. Even if the insect is 1 cm.^{2} in area, so that the average hit would be one drop per insect, some insects would by chance get 2 drops and some none. To avoid this and to allow for unevenness and losses, it is necessary to increase the number of drops. If this is done by using smaller drops, they may be too small for proper aiming and deposit in the open air ; so the poison has to be diluted, giving more and larger drops. If the insect is large, say a locust at about 5 cm.^{2}, it may still be necessary to dilute the poison, so as to get larger drops and make aiming easier. Even if the target is a sheet of water containing mosquito larvae so that a small amount of a spreading agent can be added to get even coverage, it may still be desirable to dilute and get bigger drops to reduce the loss by drifting away from the target. Finally, if D.D.T. is used as a residual insecticide, to kill insects which walk

on it in the following few days, enough of the available surface must be covered to make it probable that each insect will in fact walk on sufficient poison.

Under ideal conditions, therefore, even when the adequate dose of poison is only a few ounces per acre, it is usually necessary to increase the quantity of material to a few pounds per acre. The problem is therefore to apply the diluted poison evenly at say 10 lbs./acre. When the required dosage is as low as this, there is a prospect of economical use of aircraft to lay the poison, especially if there are difficulties in the way of other methods, such as lack of sufficient roads, and wet or rough ground. Indeed, the very speed of an aircraft may help to lay the poison evenly. Some of the facts and possibilities can be dealt with under the headings of the use of conventional aircraft for dusting, for air-to-ground spraying, and for air-to-air spraying and the use of unconventional aircraft, i.e. helicopters.

Dusting

It is already common practice to use aircraft dusting of crops commercially in U.S.A. and of locust hoppers in U.S.S.R. Little precise information is available about their results, but the practice continues, and it may be presumed that it pays. In both cases the target area is static, so that small, short-range aircraft can be used, landing in adjacent meadows and carrying on day after day. The dust cannot be aimed from any considerable height and the aircraft have to fly very low, only a few feet above the ground. This gives a swathe only 10–15 yards wide, so many trips have to be made. In Africa, it is often not possible to use such small aircraft because of lack of landing grounds, high altitude, etc. ; when the target is mobile, like a swarm of adult locusts, longer range aircraft are necessary. If they are operating 100 miles from base, they must carry a good load of poison, for otherwise too great a proportion of time is spent in travelling between base and target. Aircraft big enough to do this are too dangerous to fly at 10 feet above the ground and cannot possibly be flown so low if the ground is very broken and variably covered with trees. Consequently spraying offers opportunities of better control of aiming from somewhat greater heights and consequently of wider swathes. If suitable oil is used as solvent, the poison will stick to and penetrate the insect's cuticle more effectively.

Air-to-ground spraying.

The oily solution is poured out of the aircraft, without any special device to aid the formation of drops. The speed of movement of the oil through the virtually stationary air shatters it into drops and the range of drop sizes—the drop spectrum—depends mainly on the viscosity of the oil, and can therefore be controlled. The big drops fall faster than the small ones, so they spread out into a vertical sheet. This sheet drifts with the wind. If the aircraft flies dead across wind, the sheet drifts broadside on. The big drops hit the ground first, the medium ones later, when the sheet has drifted further, and so on. Thus the originally vertical sheet becomes a horizontal sheet on the ground, with big drops at the windward edge and small ones to leeward. Provided the wind is steady and not turbulent, the deposit can be predicted within say $\pm$ 30 per cent. By laying overlapping swathes at 50 yards intervals, fairly even coverage can be obtained.

There are two main difficulties in applying this technique. (*a*) The pilot has to have ground marks to guide him. This adds to cost and may be difficult in forests and some other situations. With adult locusts, it means that a very mobile ground party has to work at the swarm, and this makes difficulties in roadless country. (*b*) The wind must be steady in direction and speed, so that often only a short time is allowed for operations.

The method is therefore best adapted to static targets, where the local winds can be studied for prediction purposes and where marking arrangements are simpler. It is particularly suitable where the sea or a large lake makes the wind fairly regular at certain times of day. It has been used experimentally, for example, for anti-malaria spraying at Kisumu on Lake Victoria and in a number of other places, and against tse-tse in 40 square miles of the Mkuzi Game Reserve in Natal. It was tried against locust swarms in Kenya in 1945 and worked successfully under favourable conditions. It seems particularly suitable for anti-malaria spraying around towns in certain parts of Africa, where the shielding effect of vegetation is not too great and where the mosquito seasons differ from place to place, so permitting use of the aircraft during most of the year.

Air-to-air spraying.

In order to meet the need for a method of attacking migrating locust swarms, a system of spraying swarms in flight has been worked out. The idea is that the sheet of spray should be continually reinforced by additions to its top and the resulting curtain so placed that the locusts fly through it. Owing to the fact that a flying swarm has considerable depth, the drops would have chances of hitting locusts at different levels during their fall instead of hitting or missing once only as in air-to-ground spraying—so it is feasible to

use fewer drops of more concentrated material. In an ideal case, as much as 30 per cent. of the poison could be used in lethal doses, an extraordinarily high proportion. Further, it might be possible for aircraft to carry out the work without a ground party, thus gaining the full advantage of the speed of aircraft and their relative independence of local conditions on the ground. This method has not yet been tried, but experiments are contemplated.

Helicopters.

Remarks on the use of helicopters against insects depend largely on hypothesis, and little precise information is available. At the moment there is no model with adequate range and load capacity for most kinds of colonial use. Reliability is also too doubtful for use far from a well-equipped base. But if these disadvantages can be remedied, there would seem to be two great advantages in (*a*) contact with the ground; (*b*) aiming. With conventional aircraft, the pilot must depend on a ground party for guidance, and the target must be marked out for him; because of the many snags which crop up during an operation, in addition to a simple code of signals it is also virtually essential to have wireless communication between pilot and ground party. But in a helicopter one can presumably see a great deal while hovering, and come down on a small patch of bare ground to get out and look. There is thus a possibility of working without a ground party at all. As to aiming, the conventional aircraft has to use fairly large drops so as to get them down on to the target; but because they go fairly straight down, they fall on to one side of the leaves, and foliage can easily shade some of the target insects. A helicopter could use small drops or dust and blow them down with the rotor blades. The particles would then swirl about and give some penetration of vegetation and some deposit on the undersides of leaves. With helicopters it should be possible to spray a pool here and a stream there and it would not be necessary to cover the whole area, as with conventional aircraft.

Cost.

However technically satisfactory aircraft methods may be or may become, they have to give financial satisfaction. Proper estimates of costs of spraying cannot be made because converted fighting aircraft have usually been used and they have been maintained by service personnel. Maintenance and operation of such aircraft are expensive in man-power and petrol, but cannot easily be costed. What is clear, however, is that the insecticide is a small part of the cost, for a gallon of oil or less and a few ounces of poison per acre will cost no more than a few shillings. It is nevertheless essential to use as little material as possible because of the cost of delivering it from an aircraft. Aircraft spraying is not simply a matter of flying over the target and releasing the spray; it requires good pilots who are also intelligent and interested in the technique. It is unprofitable to use rule of thumb methods of spreading the poison, and in order to economise aircraft load, it is essential to have close scientific control of methods and careful checks on results. Because of the imperative necessity of ensuring that aircraft are as safe to fly as possible and the high cost of doing that, it is unlikely that aircraft will ever be used for every kind of spraying; they can probably be used profitably in certain crucial situations where other kinds of insecticide laying are difficult or impossible. Much remains to be done in discovering what the appropriate circumstances are.

Some Biological Problems in the Study of Insecticides

By Dr. C. Potter

Dr. Potter described some of the more long range problems and suggested that the specificity of effect of chemicals on insects was probably the most important problem in this field.

He said that very little direct data on this subject were available and that information was most likely to be obtained by studies in the method of arrival at the site of action and the mechanism of action of insect poisons. These studies in turn depended on a knowledge of insect physiology, much of which had yet to be acquired.

He described some of the problems involved in the biological estimation and comparison of insect poisons and gave an account of some of the problems connected with the search for new insecticides. He suggested that whereas, in the fields of industrial, medical and veterinary entomology, the problem was to provide a highly toxic non-specific insecticide, it seemed likely that specific insecticides would be required in the field of plant protection in order to protect beneficial insects: and he emphasised that fundamental advances in the study of insecticides were dependent on increases in our knowledge of insect physiology.

The Contribution of Insect Physiology to the Study of Insecticides

By Dr. V. B. Wigglesworth, F.R.S.

The purpose of insecticides is to kill insects. One of the earlier discoveries in this field was

that of Aristotle, who found that insects are killed when butter or oil is applied to the surface of their bodies. The physiological explanation of this was not forthcoming until some 2,000 years later, when Malpighi in 1669 showed that insects breathe by means of tracheal tubes opening on the body surface. That discovery has pointed the way to many advances in the use of insecticides. And so it is with the more subtle problems of insect physiology with which we are concerned to-day. The solution of these problems will not afford information of immediate practical value, but the increased knowledge will enable us to use our insecticides more intelligently and may even suggest new ways in which they can be used.

The contribution of physiology to the study of insecticides is, therefore, neither direct nor dramatic, but indirect and somewhat intangible. None the less it is of some importance, and that that belief is widely held is shown by the continued demand from the people concerned in the practical use of insecticides for more knowledge of insect physiology.

It was these demands which led the Agricultural Research Council in 1943 to establish a Research Unit of Insect Physiology. The work of that Unit as finally set up covers all those aspects of insect physiology which may be of interest directly, or remotely, to agricultural entomology ; but one important section of the work concerns insecticides, and this may best be illustrated by taking specific examples.

W. A. L. David, assisted by P. Bracey, has studied the interaction of flying insects and insecticidal mists. Nothing was known of the manner in which the fly or mosquito picks up its toxic dose when flying through such a mist or which droplets are the effective ones. David and Bracey found that the spray is picked up only in flight ; the mosquito at rest is unaffected. The greater the activity of the insect the greater the kill. Movement is necessary to ensure impaction. The very small droplets of the order of one micron in diameter do not impact. The most effective droplets lie in the region of five to ten microns in diameter.

These drops are picked up by impaction mainly on the beating wings. When a certain dose has been accumulated the insect appears to be uncomfortable and it alights and cleans its wings ; the insecticide is thus brought into contact with the tarsi of the legs and other vulnerable points through which entry can occur.

J. W. L. Beament has been studying the structure and chemistry of the egg-shell with the object of showing how these properties influence the entry of the ovicides into the insect egg. This question has an important bearing on the winter washing of fruit trees. The type of information obtained may be illustrated from the bug *Rhodnius prolixus*. The egg-shell of this insect has proved to be exceedingly complicated, consisting of no less than 7 layers. The entry of ovicides takes place only through the micropyles. These fine ducts vary in their wetting properties along their course ; their inner ends are closed by a delicate layer of wax. The effectiveness of poisons in entering the egg is determined by their relation to these obstacles.

Most insecticides used in agriculture are applied in the form of dusts. A small amount of the poisonous substance is mixed with a large quantity of inert carrier dust. The physico-chemical properties of these carriers undoubtedly influence the effectiveness of the insecticide in many ways. Studies are in progress on the part played by such factors as particle size, adhesiveness, abrasiveness and so forth. With regard to the importance of abrasion, it has long been known that certain inert dusts, acting by themselves, will kill insects. They do so by abrading the delicate film of wax which serves to waterproof the surface of the insect. When this layer is damaged the insect quickly dies from desiccation ; at the same time the entry of poisons is facilitated. It may be that the abrasive properties of the carrier dust are important in giving the maximum efficiency to the insecticide.

HUMAN FACTORS IN INDUSTRY

Under the auspices of the Division for Social and International Relations of Science, the British Association held a Conference at Leamington on Saturday, May 8, 1948, on Human Factors in Industry. The Conference was held in two sessions, the first on Working Conditions and the second on Human Relations. The Chairmen were Sir Henry Tizard, K.C.B., F.R.S., President of the Association, and Sir George Schuster, K.C.M.G., C.B.E. The attendance was in the region of 250, including representatives nominated by Government Departments, Trade Unions, Institutes, industrial firms and hospitals, as well as many others who attended in an individual capacity. At both sessions, and particularly at the second, lively discussion followed the main papers. As was to be expected, with a topic so wide and controversial, the Conference did not produce any ready-made solution of the human problems in industry, but the sessions served a useful purpose in bringing together a body of established information and suggesting that much could be achieved in the short term by acknowledging and applying it, in drawing attention to important gaps in information and suggesting how they might be filled. A summary of the proceedings has appeared in *Nature* (Vol. 161, p. 791) and the main contributions are printed here for permanent record and in the hope that they may interest and stimulate many who were not present at the Conference.

WORKING CONDITIONS

Introduction

by

Prof. R. E. Lane

Those of us whose work lies in the industrial medical field realise just as clearly as anyone else that an industrial society such as ours demands maximum production per man hour. We also know, however, that this cannot be achieved unless the workman is maintained in a state of health, comfort and good humour. The rapid development of industry has produced new problems. The difficult task which faces us is not to design bigger and better machines, but to find a way for man to live happily with the machine and at the same time maintain his individuality, to remain a healthy person and not a robot, to go on developing and expanding and not become a shrivelled adjunct of the machine. It is surely the responsibility of those who bring the man and the machine together to provide for this—for without it there is no purpose in industrial efficiency. The responsibility of industry is not fulfilled by handing a workman his pay packet—industry has a social responsibility which is now well recognised, satisfying work is a normal requirement for all people if they are to remain in health.

In a discussion of the human factor in industry it seems fitting to allot the general survey of the problem to a physician. I agree with Rees when he says that ' a doctor's training should put him in the position to make a big contribution to the planning of the life of society, and that he should be the best possible adviser on many of the human problems of the present day.' I am painfully aware, however, of the doctor's shortcomings both in the past and at the present. There is no doubt that to play his full part some re-orientation is necessary ; in the past he has tended to become exclusively concerned with gross disease and its treatment—he must be prepared to lay much greater stress on the preventive side of his work than has hitherto been the case. In my view the properly trained doctor is an essential member of any team concerned with the prevention of disease or the promotion of health, and he must certainly be regarded as an essential member of any team whose efforts are directed to increasing industrial efficiency. The rapid growth of industrial medicine in the two wars would lend support to this view.

In the past the doctor's contact with industry was too often in the capacity of a scavenger—I hope that age is past, for it is now 50 years since the late Sir Thomas Legge was appointed the first Medical Inspector of Factories. This was the first official entry of the doctor into industry and he set to work on the pressing problem of that time, the eradication of industrial disease : the steady reduction in these diseases is a lasting memorial to his great pioneering efforts. From those early days and limited beginnings great strides have been made, not only have we a greatly expanded Medical Inspectorate in the Factory Department, but other advances have been made.

In the 1914–18 war, when for the first time this country was faced with the need for maximum production, a Health of Munition Workers Committee was set up by Lloyd George in 1915—from the formation of that committee has come the Industrial Health Research Board. In the inter-war period a few progressive firms introduced medical services. By 1935 there were some 30 whole-time doctors in industry, and just before the outbreak of the last war this number had grown to 50. When, however, war's greedy demands again had to be met in this country, the number of medical personnel in industry grew rapidly, and at the end of the war there were some 200 whole-time, 800 part-time doctors and 5,000 nurses working in this field.

This extension of the doctor's activities has synchronised with changes in medical outlook; the doctor knows that the health of the individual is influenced by the environment in which he lives and works, and that work can play an important part, not only in the production of disease, but in its treatment. Society has in the past denied him the power to influence this environment and he has not been sufficiently insistent that he has a contribution to make. This has now been recognised by the leaders of the profession, and three years ago the Royal College of Physicians declared their belief that a complete National Health Service in this country required an occupational health service as an integral part of it. They pointed out, moreover, ' that hopes of social security may not be disappointed, all economists agree that the industrial production of the country must be efficient ; it cannot be efficient unless the producers are contented ; they cannot be contented unless the conditions of their work guarantee the largest attainable level of physical and mental health.'

This state of physical and mental health is related to the occupational environment, and in considering it we must always regard it as a whole. It is 20 years since May Smith pointed out that it is the *total environment* that matters, and this cannot be over emphasised. This afternoon we are to deal with physiological problems and later to-day with problems of psychology. We must always remember that this separation is quite artificial. The physical and psychological sides of this problem are inextricably bound up.

So this matter of occupational health is obviously the concern of a team. Not only the medical scientist, but equally important is the engineer, chemist, personnel officer, caterer and foreman—while balancing and leading the whole team should come the industrial manager.

What contribution can the doctor make? First he must exert an educative influence. There is a vast amount of information available on human industrial problems which is not used, but the failure of both industry and of municipal undertakings to use this information would appear to be due to their ignorance rather than to their wilful neglect. It must be admitted that many of the researches undertaken by bodies such as the Industrial Health Research Board may not have appeared to the practical man to have obvious application to industry. I think the research bodies in this field should bear this in mind, and should adopt a very realistic approach to the problems which face industry. They should be concerned not only with producing results but with interpreting them for use in the field. There is still, I think, insufficient collaboration between industry and the research organisations. Industry should be putting its problems before the research bodies, rather than leaving it to the research bodies to find their own problems. There is also a need for many research workers to leave their ivory towers and mix in the hurly-burly of industry, where they will see some of their problems in a different light and where the need for much research of an operational character will immediately become apparent to them. I still feel, however, that one of our greatest immediate needs is that the well established results of research should be made more widely known. This, I think, is one of the doctor's most important functions.

His other work may be considered under two heads : (i) to see that the worker is fit for the job ; (ii) to see that the job is fit for the worker.

(i) *Worker fit for the job.*

Allocation. The doctor has a part to play in the allocation of workers to appropriate work. Medical assessment of the workman should have a counterpart in job analysis, with a physical and psychological assessment of the needs of the job. This work is of particular value in the placement of older workers whose physical capacities become limited but who, in many cases, remain capable of years of good work if properly placed.

The need for close collaboration between the medical scientist and engineers in the design of plant cannot be over emphasised. Hitherto there has been far too little co-operation, but if we are to make full use of our ageing labour force this should receive immediate attention.

It is generally known that the wastage rate among trainees in Government Training Centres is high, yet so far as I know no scientific methods of selection are used in

allocating trainees to suitable tasks. The wide knowledge and experience gained in this field in the services during the war could well be applied to the important problem of training civilians. It is true that there are many difficulties in the training of civilians which did not arise in the services, but more efficient methods of selection are necessary to reduce the present wastage.

Resettlement. The resettlement of workers after illness or accident is a matter in which the doctor should play a prominent part. No longer can the treatment of a medical or surgical condition be regarded as complete until that patient has been re-fitted for his work and enabled to earn an appropriate wage. In other words, industry has a duty in this respect and, properly guided, will be able to hasten the return to maximum efficiency of many of these cases. Work properly graded is an important form of treatment which the doctor must learn to dispense and industry must be prepared to provide.

Casualty Service. In industry high standards of casualty service are required. Sound treatment of the cuts and abrasions can greatly reduce lost time. The importance of the trained nurse for this work is now generally accepted and the methods and techniques which have in such large measure been worked out in the Birmingham Accident Hospital are being used on an increasingly wide scale. This raises the problem of a service for the small factory. To cover these there must be some dilution of medical personnel—the training at present given to 'first-aiders' does not fit them for this type of casualty work, for which a special training is essential. I am glad to say that provision for this is likely to be made shortly.

Ancillary Services. Attention to eyes and feet will pay handsome dividends. Often one finds men working with greatly impaired visual acuity—apparently ignorant of the normal deterioration in near vision that takes place with age, and which can so easily be corrected by glasses. Ignorance of the simple remedies that can be applied to common foot conditions is also widespread, and many firms are now finding the appointment of a chiropodist of great value.

Medical Personnel. The medical personnel of the country is insufficient to provide all that modern medicine now demands. No one has yet worked out what proportion of its population this country can afford to allocate to general medical work. Whatever that figure may be it seems certain that careful attention should be given to the deployment of that force. There is an unanswerable argument in favour of an adequate proportion being engaged in reducing the burden of sickness, and an occupational health service falls in this category. The health service should be looked at as a whole. What happens at home affects the men at work, and what goes on at work has its influence on home life.

Experiments in methods of providing medical services should be made. It is apparent that certain of these services are most efficiently and most economically provided on the basis of the working group rather than the family. This applies only to a few conditions, but they are so common and result in so much unhappiness, lost time and inefficiency that it seems there is good reason for separate provision for them. Already casualty service in industry is provided—skin troubles, middle ear disease and certain eye conditions might well be treated similarly. An experiment on the Slough Trading Estate, based on this conception, is now in progress and will be watched with interest, for not only may improved industrial efficiency be achieved in this way but a better health service may be possible for the community.

(ii) *Job fit for the Worker.*

There is one point I should like to raise on this question of environmental control which will perhaps not come within the scope of the experts who will be following me. There are in industry a comparatively small number of men exposed to the hazards of occupational disease. Where these exist, however, full medical care is necessary ; for not only can much industrial disease be prevented but the reassurance provided by medical care has an important effect on the morale of others. So often fear associated with an industrial hazard does much more harm than the hazard itself.

But environmental conditions go further than industrial disease and lighting and heating, they include the general psychological atmosphere. Psychological disturbance often manifests itself by physical symptoms, and often the doctor is the first to become aware of a condition of stress in a department, and can by timely action prevent the development of more serious trouble. To do this he must have the confidence of employer and employees. He must be of industry and not merely attached to it from the outside. In such a position he can be of immense value to the management in these human problems—he can often help to a decision between experts with conflicting claims—the psychologist and the production engineer, or the personnel officer and the chemist. To do so, however, he needs much knowledge of industry and of industrial processes, as well as a profound knowledge of people. Where are these doctors? We must train them. We now have the facilities in this country, we need the guarantee from industry that there

will be employment for the best type of doctor, for if there is the demand we can produce the men. Let us remember that 'Production comes from People,' and those people need just as much expert care as do the machines they attend. That care must often be individual care, and the doctor is perhaps the best person to bring to this problem a perspective in which the human being occupies the principal place.

Coal Mining
by
Dr. C. L. Cope

Coal mining is probably unique in Britain in the extreme artificiality of all its environmental working conditions. Ventilation must be continuously maintained, noxious dusts are produced in large amounts and are dispersed into the air, explosion risks render the introduction of adequate lighting extremely difficult, heavy machinery is man operated in very confined spaces, and where machinery cannot be installed the man himself may have to work in distorted positions. To reach his place of work the miner may have to walk 1½ miles or more from pit bottom over rough roadways and through low tunnels which use up a considerable portion of his daily output of energy. In the past, in many parts of the country, his opportunities for alternative work were almost nil, and now that they are increasing he is bound by the Essential Works Order.

In addition to all this the trail of human wastage from accident and disease is greater than in any other sections of the industrial community.

Deaths on the job average about 550 per year. Accidents sufficiently severe to cause an absence of more than 3 days number 180,000 per year and have been rising steadily for a number of years.

Certifications of incapacity on account of pneumokoniosis number about 4,000 per year, and this incapacity is of course permanent. Certifications for nystagmus number 1,800 per year and for dermatitis 1,600 per year.

As if this were not enough the industry is beset with a multitude of minor and major wage disputes which are continual sources of potential friction between worker and his employer. It is perhaps not surprising in view of all this that there is a degree of absenteeism higher than that found in more progressive industries. For the typical miner is a man of fine spirit with a certain independence.

The amount of improvement that is required to remedy these conditions is vast and it is an unfortunate fact that expenditure on improvement must be balanced against the effect on the cost of coal. It is cost more than anything which militates against rapid improvement. But efforts are being made to effect a start. Ventilation conditions on the whole appear to be good and there are relatively few places where the effective working temperature exceeds 82°, the temperature beyond which efficiency begins demonstrably to deteriorate rapidly. But dust and dark persist although big efforts are being made to overcome them.

The number of cap lamps in use in the industry is rising steadily and, what is perhaps more important, the efficiency of these lamps is being improved. For efficient maintenance is an important factor in the production of the full capabilities of the cap lamp. The number of cap lamps has risen from 1 per 100 men in 1928 to 34 per 100 in 1946 and is still going up.

Recently it has become possible to install fluorescent lighting not only in the haulage ways but also at the coal face. Several collieries are now so equipped experimentally, and this is a very great advance. Two kinds are available, one for electric mains and the other pneumatic with a small turbine generator in the base of the lamp. The latter has been devised for gassy pits. At this experimental stage the former seems to be the more satisfactory. These lights are still under trial and will no doubt undergo further development. Figures are available which illustrate well the effect of progressive improvement on the actual illumination. At one colliery a survey was made recently of illuminations under naked light conditions (acetylene), under hand lamp and under fluorescent lighting. Results are greatly complicated by the fact that light intensity varies very widely at different points in relation to the lamps, this effect being aggravated by the low reflectivity of the walls.

At one face with acetylene lamps illumination at the floor varied from 0·01 to 0·77 with a mean of 0·31 foot candles. Illumination on the face itself varied from 0·01 to 0·43 with a mean of 0·29 foot candles. With electric hand lamps the equivalent figures were 0·01 to 0·03 (mean 0·02) on the floor and 0·01 to 0·23 (mean 0·06) on face. With pneumatic dafluor lamps :

floor from 0·04 to 5·50 with mean 1·25
face from 0·18 to 3·80 with mean 1·24,

a much greater contrast but higher mean. The mains lighting gives rather similar figures. Attempts to reduce the contrast and improve general illumination by whitewashing walls were made giving :

floor from 0·35 to 6·0 with mean 2·80
face from 0·16 to 2·61 with mean 1·51

The effect therefore is greater on the floor than on the face.

It will be evident that this form of lighting produces a vast improvement. At present it is not being used in gassy pits.

In general the reception has been extremely good and rapid extension of the installations is to be hoped for, the main difficulty being the cost.

It would be of the greatest value to know what effect such lighting has on nystagmus development and on accident rates. As yet the number of men affected by such lighting is very small. It is far too small in total for any effect on nystagmus incidence to be detectable in a reasonable time. As regards accidents the position is not quite so difficult. By collecting accident records from all the fluorescent lit faces through the country and comparing the results with suitable controls it is expected that some indication of trends will be detectable in about a year. This rather complex investigation is at present in hand on as accurate a basis as is feasible. Difficulties arise from the variations in accident recording systems in different parts of the country.

To facilitate investigations of this type the data required on yearly accident returns from all collieries have been reviewed and altered. A system of accident recording developed by Mr. Whitfield of the Department of Experimental Psychology, Cambridge, has been largely adopted. Attempts are also being made to introduce uniformity in recording of individual accidents throughout the country. Until this is achieved investigations of this type will not be straightforward except in small areas. As yet no data can be offered on the effects of this lighting on accident rates, for the reason that the lighting has only been in operation a short time and the number of men involved is small.

It is significant that the greatest rise in accidents occurs not from haulage or falls of ground but under the heading ' miscellaneous accidents.' These now have risen to the largest single group.

What is comprised by these is not entirely clear, but it seems probable that increased mechanisation is playing a part. It is planned to examine this problem. The importance of designing machinery in conformity with the needs of the human user was widely appreciated by the Armed Forces during the recent war. Much of the work in this field was done by the School of Experimental Psychology at Cambridge under the direction of Sir Frederic Bartlett. A young mining engineer has been appointed to work in this department with a view to adapting the experience gained there to the special requirements of the mining industry. In mining much heavy and mobile machinery has to be operated in confined dark and difficult places, and great is the likelihood that improvements in detailed design will be of value to the operators.

In the effort to combat pneumokoniosis intensive measures for dust suppression are now being put into operation. Mechanisation tends to increase the amount of dust, but this can be greatly reduced by spraying with water, or water with wetting agents or with foam. Water may also be infused into the coal strata before it is cut, to reduce the dust.

This is most extensively done in South Wales, where the pneumokoniosis incidence is highest. 78,000 yards of face are now thus treated. We have not been able to get figures for the total yardage of face in South Wales. That these dust suppressive measures can be effective is indicated by certain figures obtained by Dr. T. H. Jenkins working for the Pneumokoniosis Research Unit (S. Wales) of the Medical Research Council.

In one colliery in South Wales effective dust suppression by spray and infusion was started in 1942. Dr. Jenkins in a survey by X-ray of many hundred miners was able to collect from the number two small groups, one of which had worked in the pit in the pre-1942 dusty days for up to 5 years and the other who had only worked there in the relatively dust free period. Of the former group of 18 men, 17 showed Grade I or Grade II lung changes; of the latter group of 22 men, after up to 5 years exposure, none showed any X-ray lung changes.

There is produced here for the first time evidence that dust suppression properly applied does delay the onset of X-ray changes considerably. This is an encouraging, though admittedly very small scale pointer. It is an indication not so much of what is being done as of what good is likely to result from intensive attention to dust suppression measures on the present lines.

The extension of dust suppression measures is proceeding actively. Education of workers and management, the appointment of dust suppression officers, and of divisional dust suppression committees is actively proceeding. There are two fundamental aims. One to achieve the efficient use of existing equipment and the other to install as soon as possible suitable equipment for dust suppression in all collieries where it is needed.

The supply of materials is an appreciable limiting factor in the latter and it may be necessary to establish a system of priority since the need for dust suppression is much more urgent in some areas than in others, if one uses as criterion of urgency the incidence of detected pneumokoniosis.

It has recently been shown that miners

working underground develop an impaired dark adaptation, whether they have nystagmus or not. This impairment is considerably greater in those with nystagmus. Its cause is not known, nor is its rapidity of onset, but there is good reason to believe that it is not associated with deficiency of Vitamin A.

Underground workers also get an impairment of binocular vision, and of this again neither the cause nor the rate of onset are known.

But these changes offer a hope that the effects of various types of lighting may be followed through these changes much more rapidly than would be possible if the end results of actual nystagmus had to be waited for.

Under the auspices of the Miners' Welfare Commission an experiment in the rehabilitation of certified cases of nystagmus has been made. This so far has been on a small scale, but results have been encouraging and men so handled have shown definite improvement in morale and in general well-being.

It was mentioned earlier that it is not entirely surprising that absenteeism tends to be higher in the mining than in other industries. There is reason to believe that environmental factors may have some influence on its degree. An effort is being made to determine the extent to which this is so, and such factors as the depth and temperature of the mine, the distance from shaft bottom to working face, the thickness of the seam, and the presence or absence of pithead baths are being looked into. A survey of this type was made 20 years ago under the auspices of the Medical Research Council, but conditions have changed greatly and fresh information is desirable.

In summary it may be said that many aspects of the miner's working environment are under active review, and real efforts are being made to introduce improvements as rapidly as possible. What effects these will have on actual output, on human productivity, can scarcely be predicted. Improved environmental conditions will bring better physical health, but the medical profession is now well aware of the great importance of mental health and of the way in which this is so deeply influenced by the human rather than the physical environment.

Lighting

by

Mr. H. C. Weston

The conditions of lighting in factories should be designed to satisfy two fundamental needs of the workers, (*a*) the need for a sufficiently bright environment to promote cheerfulness, alertness, and the feeling of invigoration that finds its natural expression in mental and physical activity, and (*b*) the need to see all the essential details of the actual work-objects quickly and confidently at a comfortable viewing distance. It does not follow that conditions which satisfy (*a*) will also satisfy (*b*), and *vice versa*, though in some circumstances this may be so. But it is quite possible to have good general lighting of a factory and unsatisfactory illumination of the work, or good illumination of the work and quite unsatisfactory environmental brightness. The latter combination was only too well exemplified, during the war, in a number of factories where daylight was blacked-out, and work was done by localised artificial lighting. The depressing effect of factories having these conditions of lighting earned for them such expressive epithets as ' the dump,' and there is no doubt that this depression adversely affected output. But the absence of proper general lighting, during those hours of work when daylight is not available, is still characteristic of too many of our factories, or of parts of them. On the other hand, natural or artificial general lighting which makes a factory look bright and cheerful, and is apt to impress the casual visitor as being wholly satisfactory, may not, of itself, provide adequate illumination of many individual working areas, owing to screening by parts of machines or to the low reflectivity of the material with which operators have to work. Not long ago, a worker in such a factory brought a claim for compensation for damage to his sight and, although there was, in fact, no organic injury, there was no doubt that his work was unduly difficult to see and should have been given supplementary local illumination.

Among the conditions of lighting which are necessary for general well-being and good productivity, a sufficiency of illumination is unquestionably the most important. Recently a good deal of emphasis has been placed on the ' quality of lighting,' but, except for the spectral composition of the light, the quality of lighting is really a matter of the amounts of illumination which are provided on different surfaces which make up the external field of view, and of the amount of illumination which the eyes of workers receive directly from the light sources. That is to say, there should be such a distribution of light throughout the workroom that the contrasts, or brightness ratios, of different areas in the field of view are neither too high nor too low to be comfortable to the eyes and to allow them to function efficiently. The light should be directed and distributed so as to cast such shadows (i.e., provide weak illumination over certain areas)

as are useful for revealing the nature of objects, and to avoid them where they would conceal what needs to be seen; and at the eyes of workers there should not be any local concentrations of light, as from bright light sources or shiny surfaces which mirror them, which may cause glare. The distribution of suitable amounts of light for the illumination of different surfaces within the factory has, of course, to be achieved by suitable fenestration and by a properly designed installation for artificial lighting.

The amount of illumination required to give a factory interior a cheerful appearance depends partly on the colour, and hence the reflectivity, of the walls, ceiling and other extensive surfaces, such as those of machines, benches, etc., since it is not the light these surfaces receive but the proportion of it which they reflect to the eyes that governs their apparent brightness. So, a single standard of general illumination cannot be suggested, unless it is set high enough to make even a dirty foundry satisfactorily bright.

The amount of illumination required on the actual work-objects also depends on their reflectivity but, in addition, it depends chiefly on the apparent size of the detail the worker has to distinguish, on the contrast this detail offers to its surrounds, and on the time for which it can be kept in view. During the past 30 years much has been done to establish what levels of illumination are necessary for the comfortable and efficient performance of jobs presenting different visual tasks. From the results of surveys of lighting practice—of experimental investigations in factories—and of controlled experiments in the laboratory with synthetic tasks simulating practical ones of different characteristics, it is now possible to specify desirable values of illumination for various types of work, and to assess the requirements for particular operations when these have been analysed and graded in respect of the chief material characteristics which affect their visibility. However, this visual task analysis is not always a simple matter.

The Lighting Code prepared by the Illuminating Engineering Society in this country is based on the results just mentioned and, during the war, the levels of illumination in numerous vital factories were brought up to the standards which it recommends. Every degree of demand upon visual capacity—from the least to the highest—occurs within the range of modern industrial operations. So, since visual capacity varies over a very wide range of illumination intensities, it should occasion no surprise that numerically very different illuminations are required for different kinds of work. In fact, up to a certain point, visual capacity is proportional to the logarithm of the illumination, and only comes to its maximum when the level of illumination is 1,000 lumens per square foot, or more. Such a level is usually available only outdoors, and even then it does not prevail for long on winter days in this country.

For industrial operations involving the perception of small and very small detail—and there are more such operations to-day than there has ever been—it is thus clear enough that high levels of illumination are needed. At present, however, these exacting visual tasks are often done under conditions of lighting which must restrict the productivity of the workers and cause them undue fatigue.

Actually, it is impossible to make very fine work so easy to see as work which presents large detail—even if the best conditions of lighting are provided. As we go down the scale of apparent size, below a value which is roughly that of the detail in ordinary book-type (when viewed at the usual reading distance), progressively smaller decrements call for progressively larger increments of illumination, if the inevitable increase in difficulty of the visual task is to be made as small as possible.

For a very large number of jobs in industry quite moderate values of illumination are adequate. The Factory Lighting Regulations prescribe a minimum illumination of 6 lumens per square foot (foot-candles), without prejudice to the requirement of such higher illumination as may be necessary for fine and very fine work. However, these Regulations do not at present apply to all factories, though the Factories Act of 1937 requires that sufficient and suitable lighting, whether natural or artificial, shall be provided in every factory. But careful investigation has shown that even when the work is visually very easy, productivity may continue to rise as the illumination is increased up to more than twice the value stipulated in the Regulations. In the case of more exacting work, such as weaving and type-setting, values upwards of 25 lumens per square foot have been shown to be necessary if a high output is to be sustained. For still finer work, such as radio valve assembly, watchmaking and the like, values of illumination ranging from 60 to 150 lm./ft.^{2} are sometimes used, and are certainly desirable. The illumination provided for surgical operations is often of the order of 300 lm./ft.^{2}, and some of the finest work in industry needs to be similarly well illuminated. In very fine work, however, the individual field of attention is usually quite small, and it is, of course, only over the actual working areas that very high illumination is required. But the general

illumination should always be suitably proportioned to the local illumination, so that there is no great contrast between the brightness of the work and that of the general field of view.

Upon the illumination required for the work, and the daylight factor at the place where it has to be done, depends the number of hours during the working day, in different seasons, when adequate natural illumination can be expected. The ratio which the daylight illumination at any point in a factory bears to the simultaneous illumination given by the open sky is fairly constant, and it is this ratio—expressed as a percentage—which is termed the daylight factor for the point considered. Clearly, the higher the daylight factor can be made at all working points the longer will it be possible to dispense with artificial lighting. Not that artificial lighting cannot be made very good, and even better than daylighting for some purposes. But in the case of multi-storied buildings it is not usually practicable to provide for a daylight factor of more than 3 per cent. over any considerable proportion of the working area. Even with this value, and on the shortest day of the year, it is only for about four hours that the interior daylight illumination can be expected to be not less than 15 lm./ft.^{2}, and this is inadequate for numerous industrial operations. The average daylight factor in most of our older factory buildings which are lighted by side windows is well below 3 per cent. For example, in numerous engineering shops it is 1·5 per cent. or less, and there are many places where it is so low that artificial lighting is necessary all day all the year round. Conditions are generally a good deal better in single-storey buildings having the familiar north-light saw-tooth roof. Even so, the location and construction of machines or plant prevent the access of adequate daylight to some working areas, so that local artificial lighting is always needed.

There is a good deal to be said in favour of naturalizing artificial lighting in certain respects, especially in those factories—and they are many—where it has to be used continuously, or for long periods, to make good the deficiency of daylight. This means making it as unobtrusive as possible and, preferably, using light which is similar in spectral quality to daylight. Providing it is well-planned, fluorescent lighting satisfies these conditions very well. Fluorescent lighting, like any other artificial lighting—and even daylighting—can be unsatisfactory if it is unskilfully done, and especially if insufficient illumination is provided. It has been said to be harmful to the eyes, and misconception of it on this score is not entirely confined to non-medical people. Those who complain about artificial lighting so often do not discriminate between the nature of the light or illuminant, and other characteristics of the lighting, and of the installation providing it. There is still no shortage of unskilful and unsuitable artificial lighting in factories which justifies various complaints, but it is only fair to say that there is no evidence that the commonly used artificial illuminants—including ' fluorescent light '—are themselves harmful.

The changing age distribution of the industrial population should be taken into account in planning the lighting of new factories and the re-lighting of existing buildings. Especially about artificial lighting, complaints come most frequently from workers in the older age-groups. But recent experimental evidence shows that, in close inspection tasks, visual efficiency begins to decline in early adulthood. This decline occurs at all values of illumination, but the actual loss it entails as age advances varies with the illumination of the work. The achievement of good visual conditions in industry is not, however, simply a matter of lighting. It also depends on factory decorations, on the design of worksights—that is to say, of the size, position, colour and background of the work-objects—and on the provision of appropriate optical aids. The latter—which are not as extensively used as they might be—can often increase the workers' comfort and productivity very considerably.

(Mr. Weston's contribution was illustrated by lantern slides.)

Heating and Ventilation

by

Dr. Thomas Bedford

A satisfactory system of heating and ventilation must be capable of providing a pure and refreshing atmosphere and of maintaining a suitable degree of warmth.

Ventilation Requirements.

The first requirement is that there shall be sufficient ventilation to provide a respirable atmosphere ; enough fresh air must be supplied to maintain an adequate concentration of oxygen and to remove the products of respiration at such a rate that no ill effects arise from excess of carbon dioxide. In gas-tight compartments, such as submarines, difficulty may arise from excess of carbon dioxide or deficiency of oxygen, but in ordinary buildings no such trouble need be feared.

Most of the standards of fresh air supply which have been recommended during the past century have been based on the amount

of fresh air which is necessary to keep body odours down to an imperceptible or a barely perceptible level. The most recent work on these lines suggests that as a general rule fresh air should be supplied at the rate of not less than about 600 cubic feet per person per hour, and that preferably there should be 1,000 cubic feet per person per hour.

It is clearly desirable that a room should be free from objectionable body odours, and for that reason ventilation standards such as have been mentioned are justified. A further and more important reason for insisting on adequate ventilation is the need for keeping the bacterial contamination of the air to as low a level as is practicable. In recent years it has been clearly demonstrated that some infections can be spread by air-borne organisms, and except in special circumstances the provision of good ventilation is probably the best preventive measure. In the present state of our knowledge it is not possible to give any precise figure as to the amount of ventilation required for this purpose in various circumstances. The Factory Department pamphlet on the ventilation of factories recommends a ventilation rate of six air changes per hour. In most instances this represents good ventilation, and if such a rate can be maintained it will probably provide a reasonably clean atmosphere from the standpoint of bacterial contamination.

In some industrial operations, harmful gases, vapours, fumes or dusts are given off. Precautions are needed to prevent the escape of these substances into the general atmosphere of the factory, but this is a specialized subject which cannot be dealt with at this time.

Warmth and Comfort.

Research has shown that for persons doing very light work the air temperature during the winter months should be as nearly as possible 65° F. It is undesirable that it should fall below 60° or exceed 68° F. (It should be noted that the Factories Act, 1937, requires that in rooms where a substantial portion of the work is done sitting and does not involve serious physical effort, the temperature must not be below 60° F. after the first hour of work.) For more active work somewhat lower ranges of temperature are sufficient. For active, yet light, work a temperature of 60° to 65° F. is suitable, while for work requiring more muscular exertion a temperature of between 55° and 60° F. is desirable.

In hot weather, unless there is full-scale air-conditioning, it will be impossible to keep factory temperatures down to the levels suggested for winter, nor are such temperatures desirable in very warm weather. With copious ventilation, however, it should be possible to maintain in summer a shop temperature only slightly above the outside temperature.

The temperatures mentioned above are those which will generally be found comfortable. In the interests of working efficiency and of fuel economy over-heating should be avoided.

In winter the internal surfaces of the walls and roofs of lightly-constructed buildings may be several degrees cooler than the internal air temperature. Owing to the radiation of heat from their bodies to these cold surfaces, persons working in such shops may need rather higher air temperatures than have been recommended, or some additional radiant heat. On the other hand, where much radiant heat is given off from heating apparatus or from manufacturing plant some compensatory reduction in the air temperature, or increase in the speed of air movement, may be desirable.

Even at ordinary room temperatures a high atmospheric humidity tends to cause feelings of stuffiness. At such temperatures the moisture content of the air should not exceed 70 per cent. of the saturation value, and should preferably be well below that figure. In the average factory where there are no wet processes the humidity will generally be satisfactory if the fresh air supply is adequate.

At high temperatures, when much of the heat produced by the body must be dissipated by the evaporation of sweat, high atmospheric humidities cause great discomfort and may even be injurious. Discomfort is generally felt when the wet-bulb temperature exceeds 70° F. In situations where high humidities are unavoidable their effects can be mitigated to a considerable extent by the provision of vigorous air movement.

During the winter season the air speed in an ordinary factory is usually greater than 20 feet per minute and commonly averages about 30 feet per minute. In summer weather air speeds distinctly higher than these are desirable. At air speeds much below 20 feet per minute the air tends to seem dead and feelings of stuffiness are likely to arise, especially when the air temperature approaches the upper limit of the comfort zone. Good air movement is necessary to provide an invigorating atmosphere.

With some methods of heating the temperature of the air in the upper parts of the room is often found to be much higher than that near the floor. This tends to produce a feeling of stuffiness in the head, while the feet are cold. A system of heating which produces appreciable temperature gradients of this type is not desirable.

To sum up, the physical requirements for

a pleasant and invigorating environment are :

(1) A room should be as cool as is compatible with comfort.
(2) There should be adequate air movement but no local draughts.
(3) The air movement should be variable rather than uniform and monotonous, for the body is stimulated by ceaseless change in the environment.
(4) The relative humidity of the air should not be above 70 per cent. and should preferably be much below that figure.
(5) The average temperature of the walls and other solid surroundings should not be appreciably lower than that of the air and should preferably be higher. The combination of cold walls and warm air often causes feelings of stuffiness.
(6) The air at head level should not be distinctly warmer than that near the floor, and the heads of the occupants should not be exposed to excessive radiant heat.

Warmth and Working Efficiency.

When a task requires considerable manual dexterity uncomfortably low temperatures are undesirable, for as the hands become chilled their dexterity diminishes. In one series of experiments the investigators imitated an industrial process by assembling the links of a bicycle chain. When the room temperature was 50° F. the time required to perform the test was 12 per cent. longer than when the temperature was 62° F. (Vernon, Bedford and Warner, 1930).

In another series of laboratory experiments the effect of temperature on the work done by a group of men while weight-lifting was studied. The men worked at their own discretion and were paid a bonus on the amount of work done. At a temperature of 75° F. they did 15 per cent. less work than at 68° F. Other observations have shown that when work is done at a constant rate an increasing strain is imposed on the body as the temperature of the environment rises.

The effect of high temperatures in reducing the efficiency of persons engaged in manual work has been observed in various industrial investigations. In a study of coal miners it was found that the speed of working diminished, and the amount of time taken in short rest intervals increased, as the temperature rose, so that as the dry-bulb temperature rose from 59° to 82° F., the working efficiency of the miners was calculated to decline by 41 per cent. (Vernon, Bedford and Warner, 1927).

Further evidence of the adverse effects of excessive warmth on industrial efficiency is obtained from an examination of seasonal fluctuations of output. It has been shown that in heavy work, especially when it involves exposure to high temperatures, output undergoes a strong seasonal variation. It is generally greatest in winter, least in summer, and intermediate between the two in spring and autumn. Such variations have been observed in the iron and steel and tinplate industries (Vernon, 1919, 1920) ; and in glass manufacture (Farmer *et al.* 1923).

There was a close relationship between the external temperature and the output from tinplate rolling mills. The output in August was about 10 per cent. less than in December and January. In hot industries such as tinplate manufacture ventilation is very important. Large supplies of cool air reduce the temperature and increase air movement. The effect of good ventilation was shown by Vernon in a comparison of the seasonal variations of output in different tinplate works. In the best-ventilated factory the output in summer was only 3 per cent. less than in winter, while in the worst-ventilated factory the summer output declined by 13 per cent. It was estimated that in the worst-ventilated factory the output on the hottest days was probably 30 per cent. less than in the coldest weather.

In the weaving of certain qualities of cotton and linen cloths it is customary to carry on the work in artificially humidified air at a high temperature. In hot and moist air warp breakages are less frequent and production is greater than in cooler and drier atmospheres. This relation holds up to a certain point, but Weston (1922) noted that in linen weaving production began to decline when the wet-bulb temperature exceeded 73° F. A similar effect was noted by Wyatt and others (1926) in cotton weaving. With high humidity production fell when the air temperature exceeded 75° F., even though the number of warp breakages continued to decrease. The adverse physiological effects on the weavers more than counterbalanced the increasingly favourable physical conditions for weaving.

It is a matter of common experience that one's inclination for mental effort may diminish in hot environments, but it has not previously been clear whether any reduction in mental efficiency in hot surroundings is due to reduced capacity for such effort, or merely to disinclination for it. In a recent investigation Mackworth (1946) has demonstrated the diminished capacity for mental performance in hot environments. Hot and moist atmospheres seriously impaired the accuracy with which trained wireless telegraphy operators could record messages transmitted over the telephone at constant

speed. As the wet-bulb temperature rose from 75° to 95° F. the average number of mistakes per hour increased nearly eight-fold. It is interesting to note that the exceptionally competent members of the group were less affected by the difficult conditions than men regarded as very good operators, while men of ordinary ability showed the greatest deterioration of all.

Temperature and Accidents.

Besides affecting comfort and working efficiency, temperature conditions also exert their effects on health and on the accident risk.

The first recorded observations of the influence of atmospheric conditions on accident frequency seem to be those made by Vernon (1918) during the war of 1914 to 1918. At a large munition factory the average temperature and the number of cuts and other minor accidents incurred at work were recorded. From these records it appeared that accidents were least frequent when the temperature lay between 65° and 69° F. Further observations in other factories confirmed this conclusion. Compared with the rate at temperatures between 65° and 69° F. the mean accident frequency for men and women was 23 per cent. greater when the temperature rose above 75° F., and with temperatures below 55° F. the accident frequency rose by 32 to 35 per cent. (Osborne and Vernon, 1922).

Through the introduction of an air-cooling plant at a gold mine in Brazil the wet-bulb temperature in the deepest workings, 6,000 feet below the surface, was reduced form 89° to 80° F. The reduction in underground temperature was accompanied by a substantial decline in the number of fatal accidents.

Observations in British coal mines have shown that the temperature of the working place has a distinct influence on the liability to accidents. Thus, during two statistical periods, each of two years duration, the accident frequency rates for coal-face workers employed in seams where the temperature was 80° F. or more were 77 per cent. and 30 per cent. higher than the corresponding rates for men working at temperatures below 70° F. For the men working at temperatures of 70° to 79° F. the accident rates were intermediate (Vernon, Bedford and Warner, 1928, 1931).

This study of coal miners also showed that the temperature of the working place affected the relation between age and liability to accidents. Various investigators, and notably Newbold (1926), have shown that there is a definite correlation between age and the frequency of industrial accidents. Young people are more liable to incur accidents than older persons. In the study of coal miners it was found that on the whole the frequency and severity of accidents were both at a minimum in men aged from 30 to 39 years. The increased accident frequency amongst the older men was not due to a disproportionate number of minor accidents, for the proportion of accidents causing absences of less than 20 days decreased steadily with increasing age, while the proportion of more serious accidents increased. The influence of temperature on the relation between age and accident frequency is shown in the Table.

Accident Frequency of a Group of Coal-face Workers in relation to Age and Temperature

Age Group	Accidents per 1,000 men per year in seams where the temperature (°F.) was:		
	Under 70°	70° to 79°	80° or more
Under 30 years	203	263	289
30 to 39 years	186	219	251
40 to 49 years	180	232	299
50 or more years	191	331	344

Men working at temperatures below 70° F. had the lowest accident rates and those at temperatures of 80° F. or over had the highest. In the coolest mines the accident rate at first declined with increasing age, reached a minimum frequency in the 40 to 49 age group, and then increased slightly in the older men. In the remaining two warmer groups of pits the minimum frequency was reached at ages 30 to 39 years, but whereas in the pits at 70° to 79° F. men aged 40 to 49 years had only slightly more accidents then those aged 30 to 39, in the pits at 80° F. or higher temperatures there was a considerable increase in accident frequency from the 30 to 39 age group to the 40 to 49 group. Fatigue can be an important factor in accident causation. Hard work is more trying when done at high temperatures, and it seems likely that the change in the relationship between age and accident frequency is due to fatigue.

Sickness in relation to Atmospheric Conditions.

It is generally accepted that overcrowding and bad ventilation are injurious to health, and the effects of lack of ventilation on industrial sickness have long been recognised. Men who perform heavy work at high temperatures, and who are liable to be exposed to sudden changes of temperature, experience

more sickness than those who work under more equable conditions. Vernon and Rusher (1920) studied the sickness records of 20,000 iron and steel workers over a six-year period. Steel melters had a sickness rate 23 per cent. greater than that for the whole body of workers, and the rate for puddlers was 20 per cent. greater. Tinplate mill men and rolling mill men had sickness rates 18 and 8 per cent. above the average. The puddlers and steel melters suffered from an excessive amount of rheumatism and respiratory disease. Their work involves occasional bouts of very heavy exertion followed by intervals of rest or lighter work, and they therefore incur risk of chills. The tinplate mill men work almost continuously, and are therefore not so liable to chilling. These men did not lose more time from rheumatism than that lost on the average by all workers. The mortality of steel workers from respiratory disease was twice as great as that of all occupied and retired civilian males. It is the experience of the Metropolitan Life Insurance Company that iron foundry workers, iron and steel mill workers, and coal miners, have mortality rates for pneumonia much in excess of the rate for all occupations (Yaglou, 1937). In this country the sickness absenteeism of coal miners working in hot mines has been shown to be higher than that for those working in cooler pits (Vernon, Bedford and Warner, 1928, 1931).

There is evidence that relatively small differences in temperature may exert an influence on the amount of sickness experienced by factory workers, and further observations at yet another factory point to ventilation as the chief factor responsible for some difference in sickness rates.

Some Practical Considerations.

Enough has been said to demonstrate the important influence of atmospheric conditions on the efficiency and general well-being of the industrial worker. It is not possible here to discuss in detail the various methods by which a satisfactory working environment can be maintained, but it is desirable that emphasis be laid on certain important points.

Firstly, the ventilation and heating of a factory should be under the effective supervision of some person who is trained to pay special attention to the proper use of the appliances and arrangements provided. Particular care should be taken to ensure that the temperature is suitable for the work which has to be done, and that over-heating is avoided. Unduly low temperatures at the beginning of the day and excessive warmth later are still too often observed. These troubles can be avoided by adequate supervision.

Any method of heating which causes the temperature of the air at head level to be much above that at floor level should be avoided. In the past many factories have been warmed by means of steam-pipes suspended overhead. Steep temperature gradients are often caused by this arrangement, with much consequent discomfort and waste of fuel.

When a building is warmed by the circulation of warm air, whether from a plenum ventilation system or from suspended unit heaters, the air supplied by the fans should not be very hot. When the air is supplied at a temperature much above that of the room stratification occurs, and the hot air accumulates at the higher levels. Air-heating systems should discharge large volumes of relatively cool air, rather than smaller volumes of very hot air. Ideally, the entering air should be at the temperature which it is desired to maintain in the building, and the heat losses through the fabric of the building should be provided for by some other means.

HUMAN RELATIONS

Introduction

by

Dr. R. F. Tredgold

Human Relations is a term which has recently come into fashion to describe the way in which human beings behave to one another. Obviously there are certain particular relationships to which we generally pay much attention. Much has been written, said and thought, for instance, on the relationship between husband and wife, parent and child, or brothers, or comrades in arms ; but what we are here to discuss are the relationships in industry. It has been recently remarked that the master-servant relation is one of the oldest in the world, second only to that of the husband and wife. It is difficult to justify this on historical grounds, but no doubt this particular relationship has long been studied. The relations, however, between the various members of a firm are more complex, and it is interesting to see just what difficulty we have in finding words to describe them—a difficulty which reflects our lack of familiarity with the idea. There is no one simple word

which is in common use for the relations of workers to each other—if we except ' fellow-workers,' which has also political connotations—and for relationships between different levels we have borrowed the term ' leadership' from elsewhere and the term ' subordinateship ' is so obviously cumbersome that it speaks for itself.

We must admit, then, that we know far too little about the fundamentals of these relations ; we do not know why people work, or why not : why people stay away sick when they are not ill, or stay at work when they are : why managers sometimes behave like human beings to their workers, and tyrants to their children, or sometimes *vice versa* : why trade unions are sometimes sweetly reasonable, sometimes not. In fact we are singularly lacking in our knowledge of the makings of social skill. Moreover, it is by no means accepted that social skill is even necessary : promotion is often made on purely technical grounds, and whether or no the technician has social skill is disregarded, until someone innocently wonders ' What has come over Joe ? He used to be a good worker, but promotion seems to have spoilt him : and he now gets everyone's back up.' In fact, of course, Joe is more to be pitied than anyone else : for his lack of social skill—of getting on with others, or working through others—should have been noted and remedied before he was promoted.

I say ' remedied,' and that is another question ; for some people believe it cannot be remedied, people who believe leadership is innate, and cannot be altered by training. I think the war showed us the error of this, and most firms now have training schemes for supervisors, and some for higher leaders—naturally it is a case of the higher, the fewer.

But we can scarcely afford to be complacent, for even where the essentials of leadership are being studied and taught, the study of subordinateship and of fellowship is less advanced, and Elton Mayo goes so far as to place the failure of communication among individuals and groups as the most tragic and significant failure to-day. He reiterates his statement that if our social skills had only kept pace with our technical skills, there would not have been a second European war. Has there been any progress in social skills since the days of the Greeks?—if not, why not?

The study of human relations is, of course, nothing new. It has been a subject of speculation by philosophers and kings, demagogues and dictators, religious leaders and poets for centuries, and there is no doubt that many have had a very profound understanding of the mainsprings of human conduct—as we can learn in their writings.

As a matter of fact not so many people nowadays seem to read their writings : but their value is still undoubted. There are, of course, many modern books too, and one may read a long and learned account in some English or American textbook and be left (occasionally) with the feeling of how well it has hit the nail on the head, until suddenly one realises that it is exactly the same point as was expressed in the Bible perhaps or by Plato 2,000 odd years ago, and expressed there, it is embarrassing to add, much more shortly and succinctly than by our modern writers, be they industrialists or psychologists.

Unfortunately it is only too evident that the views of these leaders have not always been acted upon by their followers, and on the whole influence human behaviour to-day very little. In industry, for instance, it seems fair to say that the patterns of behaviour are due more to the historical experiences of the last 100 years than to the tenets of the religious and philosophical leaders of the past 2,000. But lip service is still paid to the latter, and a good deal of excuses are thought out to explain why so many of us do not let their tenets affect our behaviour. The problem, therefore, seems to be to bridge this gap.

If one is interested as to why this should be, one is struck by the fact that, although these tenets are often laid down in a dogmatic way, they are not often explained, or the reasons why they are held are not explained, even to the disciples of the people concerned, and less often still to the general public. We agree, as I think we must, that we are much more likely to act on a feeling if we have come to understand fully the reasons for it (witness the importance placed by Montgomery on seeing that every soldier knew the reasons for his part in the battle), we can see the value of explanation in affecting behaviour. There is, of course, another example in medical practice.

It seems then that some improvement of human relations could result from an explanation of their basis on a very much wider scale than obtains at present.

If one attempts to do so, one meets a number of prejudices right at the start—of which the greatest to my mind is the prejudice against thinking at all, or at all clearly, about the facts of the mind.

Those who do delve into the recesses of the mind (which for some reason are likened by many to a sewer or a sink) are therefore regarded with some suspicion. They are not quite nice : it is indecent to probe into such things, and perhaps a little impious. It is interesting to record that a few centuries ago the same sort of objection was raised against the earlier anatomists. No doubt this is

partly a dislike of new things, but it is probably partly too something deeper—a reluctance to look at the workings of one's mind which is based on fear. After all our mind is our latest acquisition—the only thing which distinguishes us from the beasts, however unflattering that may be—and it is by no means pleasant to envisage even the possibility of it being in any way imperfect. So that we are afraid to look and see, and when we meet abnormality it is easier to conceal it than to face up to it : which is the reason for much of the horror and fear which quite unnecessarily surrounds mental illness, and also the reason for the jokes against the inmates of mental hospitals—for a joke is often a useful defence.

Moreover the prejudice is increased by other reasons—some people obviously sheer off the subject because it seems too hard for them. Some of my colleagues in this country and in America have written very long textbooks on the subject, which are by no means always easy to understand and have tended to emphasise their points of disagreement rather than their points of agreement ; this has not unnaturally made it seem even harder. But the subject can be made simple and is already one which is interesting to everyone.

It seems to me, therefore, that we have two steps to take at the outset—firstly, to study the prejudices of each other (and ourselves—which is a bit harder), to remove them, if we can, and if we cannot, to allow for their effect ; and secondly, to provide simple explanations for much more of the workings of mental behaviour than many people have to-day. So will an increasing body of agreement be built up ; also, perhaps, an increasing habit of co-operation.

I was originally asked to talk with special reference to rehabilitation and I might have said more about the work of the Rehabilitation Centre where I have been working : but it would be rather out of perspective to discuss that aspect of human relations in detail here. A Rehabilitation centre is a particular place where good human relations are essential, but in this meeting I think it is better to look at it the other way round. Good human relations do in fact provide mental (*and* social) rehabilitation in any circumstances, and the fact that so many of us are below our full mental and social health, and so need rehabilitation, is because our human relations are far from perfect.

The work of such a centre shows very clearly the success to be gained from paying attention to three activities of life—physical, mental and social. So many schemes neglect one of these—generally social. Yet the man whose symptoms are often largely social is so common : he is a misfit, he is shy, he is over-aggressive, and these symptoms exaggerate his mental and even his physical symptoms. Hospitals as a whole tend to neglect the need to increase the patient's social activity. Indeed the atmosphere of many is to spoon feed and so increase the lack of social responsibility. Someone said of our work, ' I suppose your aim is to get everyone to do things for themselves '—which sounds at first sight unexceptional. But I think we try to go one better—to get everyone to do things for each other.

Incentives

By Mr. D. Chapman

Before the war incentives to increase production were almost always considered in terms of premium or bonus payments. Many of these schemes had the effect of reducing piece rates as productivity increased : others in effect paid higher piece rates as productivity increased. There are obvious objections to both these procedures and many firms decided on the basis of their experience to use straight piece rates.

The experience of workers in the period of mass unemployment, however, led to considerable resistance to the operation of financial incentive schemes. They argued that these were employed in the long run to reduce piece rates and as a means of selecting the slower workers for dismissal. As a result there was very much friction between operatives and rate-fixers—even violence and the informal establishment of norms designed to protect the slower worker.

Incentive schemes were often in practice associated with attempts to improve production by replanning processes, new methods, and increased division of labour, which were regarded (often with justice) as attempts to reduce the power of organised craft groups, and to increase the proportion of unskilled and semi-skilled workers to craftsmen. As a result violent antagonism exists in many industries to piece work, bonus schemes, redeployment of labour, time and motion study for job simplification, and to all other methods of increasing productivity.

At the present time, although many of the features of the pre-war situation are absent, large numbers of operatives are by no means convinced that full employment is anything but temporary, and they are therefore unwilling to consider changes in the organisation of their work which might weaken their position if unemployment returns.

There is likewise unwillingness to consider additional effort, partly because of P.A.Y.E. —not so much as the result of a calculated

assessment of its effect, but as a result of a feeling of personal injustice, that effort or skill is penalised—and partly because additional earnings will not provide food, clothing, furniture or housing.

It is important likewise not to underestimate the factor of national morale which the evidence of many indices suggests has declined over the last thirty years. This factor, masked by poverty and unemployment before the war, is now more evident.

The question, therefore, arises, what if anything can be done in the present situation? The answer is that a great deal can in fact be achieved if the social problems involved are understood and tackled in the correct way. That is, if the approach is to the working group concerned. To tackle production problems by exhortation on a national scale has little or no effect, and may even have a bad effect.

In the final solution the financial incentive will play an important part, but its effectiveness will depend on the total situation. Of the working situation it is only necessary to mention the obvious requirements of good management, intelligent and sympathetic foremen and departmental managers, democratic participation of workers in management, and effective but not paternal welfare schemes, satisfactory lighting, heating and sanitation.

It should, however, be borne in mind that the presence of backward plants in an industrial town will colour the attitudes of workers in other factories.

The problem is to devise ways whereby absence and lateness may be reduced, new methods of working including redeployment be accepted, the attention of the operative directed to finding ways of reducing effort, and co-operation between individual operatives, groups of operatives, and operatives and management increased. For this to succeed it is important that a system of payment by results should be adopted which, to quote from the report of the 'Cotton Manufacturing Commission':

- is 'related to the skill and effort which the task requires and the efficiency with which it is discharged';
- is 'related to existing levels of wages in the industry';
- will 'ensure the fullest use of skilled labour and a proper reward for the efficiency of operatives and management';
- is 'based on factors easily ascertained and checked.'

In many industries, and particularly in cotton weaving, methods of payment, although including elements of payment for output, do not meet these requirements. Piece rates, agreed as the result of struggle and negotiation, may persist long after the conditions in which they were valid have passed, and may actually penalise extra effort.

To devise such methods of payment and to replan work for increased output is now an established and highly developed skill, but social processes necessary to ensure their adoption by operatives (and often management) are undeveloped.

The resistances will only be overcome if the initiative for improvement can come from below as the result of the understanding and agreement of the working group itself. The creation of production committees within the works is an obvious first step, but it should have alongside it a developed campaign in the trade union, not at a national level, but at the district and factory branch level. The trade union branch with the management should share responsibility for improved methods. It is a matter of great urgency that trade unions should accept this responsibility. Outside consultants employed by management often fail to get their schemes accepted.

Some of the improvements that are needed are of the most elementary kind, but depend on improved social relations. Thus, in a weaving shed where the average efficiency is 76 per cent. a few weavers who are related or are very close friends, and who co-operate to keep looms running, maintain efficiencies between 84 per cent. and 93 per cent.

There are short-term social devices which have value: thus, during a 'production drive' trade unions and informal operative groups may agree to allow experiments. In one case an efficiency competition amongst learner weavers raised average efficiency by about 10 per cent., but had an overall effect by raising the level of aspiration of other operatives who had previously resolved not to be told their individual efficiencies. When these were known many other weavers began to improve their own rating.

It is important, however, to be on one's guard against facile solutions which have had effects in the long term. Thus, the reorganisation of certain processes for one works, which were formerly done by teams of men, so that the individual production records could be kept, and individual bonuses paid instead of group bonuses, resulted, in a short time, in the elimination of a number of highly skilled but older workers from the trade as they were unable to maintain the speed of working of their colleagues, so that increased productivity resulted to some extent from a reduction in the average age of the working group.

The Problems of Deterrents and Applied Social Science

by Dr. A. T. M. Wilson

Introduction.

Discussions of industrial problems are, at the moment, characterised by confusion over an agreed frame of reference within which human behaviour in industrial communities can be understood. In publications and reports on industrial behaviour such notions as that of the donkey, the carrot and the stick have become unpopular ; but a consideration of the practical policy of industrial groups of very varied kinds supports the conclusion that simple notions of this sort represent a theory of human motivation which is still widely used despite its inadequacy. This inadequacy represents, at the least, a challenge to those concerned with social science in the community. It is, of course, true that understanding human behaviour in society is never a simple matter, and that there is, in consequence, a case to be made for the every-day use of rule of thumb methods. Such methods, however, may become dangerous where large scale policy is concerned ; and the present situation in this country calls for an examination of the adequacy of any point of view regarding human motivation which is in wide current use, in or out of industry.

In what follows there are given, first, some general observations concerning human behaviour and some general points for discussion, arising from these observations. Secondly, there is a brief description of some groups of experiments in social psychology which appear to be relevant to the matters under discussion. Thirdly, some current difficulties of industrial production and industrial morale are discussed ; and finally a point of view is expressed regarding the rôle of social science in facilitating agreed social change.

1. Some general observations.

(a) *Throughout our lives we are members of social groups.*

This truism is particularly important when we have to consider what are the significant factors affecting human behaviour. The inadequacy of most psychological theories of human personality and behaviour is now widely recognised ; whether we look on human beings from the point of view of biochemistry, of biology, or of psychology, it is not possible completely to isolate the individual from his environment without producing a dangerous artefact of thought. It should further be said that, from the point of view of psychology, the important component of the human environment is other human beings ; and it is this fact which has led to the increasing recent emphasis on the study of human relations.

(b) *Social behaviour is greatly influenced by the effects of past and present group membership.*

The significance of the family as a main agency, through which cultural patterns of behaviour and value-systems are transmitted from one generation to the next, is now generally agreed. Equally the effect of formal group membership at school and informal group membership in the community cannot be gainsaid ; but the extent to which current group membership can influence behaviour, although widely agreed in theory, is much less widely accepted in practice ; and there is certainly scope for repetition and development of existing work in experimental social psychology which would give some possibility of indicating the limits within which the behaviour of particular individuals is modifiable by membership of a particular group within its own social ' climate.' As a specific instance of this last observation there is a manifest contrast in the behaviour of an individual at home as, e.g., a husband with wide responsibility for his family and, on the other hand, at work, as a worker with restricted responsibility and heavily sanctioned controls of his behaviour.

In practice the points just mentioned mean that simple notions of the ' cause and effect ' type can never be adequate in studying human behaviour, either in or out of the industrial field ; and as a corollary, simple solutions to apparently simple problems are equally unlikely to prove adequate in practice. With regard to what are called ' incentives ' and ' deterrents,' the introduction of ' incentives ' or the removal of ' deterrents ' without reference to the total setting in which the individuals concerned are at work, does not necessarily produce desired changes of a lasting type. For example, where bad physical conditions are held to be a ' deterrent ' to productive efficiency, the introduction of good physical conditions may have no effect, or a transient effect, or a lasting effect, depending on the total setting in which this change takes place. More directly, experience shows that the interpretation which workers place on improved physical conditions—for example, that it is an expression of real benevolence or, alternatively, of anxiety and guilt on the part of employers—may be a primary factor in determining the result of changes of this kind.

Human behaviour, then, cannot be understood—or even adequately described—without reference to the effects of past and present

group membership or the pattern of culture—in the anthropological sense—in which we live. But to say this may still fail to give adequate weight to the complexity of the factors which affect human behaviour—a complexity which has not so far been adequately simplified by scientifically-based generalisations of high probability. It is important to notice that psychology has recently arrived at a stage where, in common with other fields in which scientific method has been applied, there has begun to develop a realisation of the need to base investigations and practical work within a theoretical framework of the type of field theory which has by now a long and successful history in relation to attempts to understand and harness gravitational and electrical forces.

2. Some relevant groups of experiments.

(*a*) It is important to consider whether any indications exist as to the maximum of productivity or co-operative behaviour which might potentially exist in human groups under optimal conditions. In much industrial practice the notion is implicit that without fear and disciplinary control, co-operative behaviour cannot rise to any economically adequate level. Although, in fact, low efficiency in productive and co-operative behaviour is widespread, there is at least some evidence that this situation may be very much affected by the ' social climate,' by the morale or, in more general terms, by the field situation in which industrial groups find themselves. In one particular experiment in which something like a hundred soldiers were freely permitted to do nothing (Bion and Rickman) [1] the investigators came to the conclusion that an urge to constructive activity is a natural impulse which, under proper circumstances, will always seek expression. The experiment also demonstrated that, in the absence of an imposed discipline men will establish a discipline among themselves, and that such a self-imposed discipline, drawn up and freely selected by a group, needs little to make it effective, and is willingly carried out by the individual members of the group. It may be added that there exist investigations on a smaller scale confirming the potentiality indicated above.

(*b*) An example of a second kind of experiment was conducted with a group of workers in an American factory. To these workers, after various stages of relationship had developed, an investigator said, ' Suppose you set your own conditions of work, what would you do? ' The men concerned then drew up a detailed plan which contained among other things modified rest pauses ; removal of disciplinary time-keeping ; a slight change in bonus rates but a basic wage similar to that of the rest of the factory. By agreement with the management this plan was put into operation and resulted in a level of production which was beyond the maximum calculated by production engineers for the machines concerned. In this experiment the only basic condition of work laid down was this : that there should be no problem or factor affecting the work of this group of men which would not be discussed with them. The total situation under which an experiment of this kind could be conducted is, of course, important ; but for the moment we are simply concerned with the finding that industrial production is likely to be well below human potential given optimal conditions of work in the psychological and social sense.

(*c*) A number of experiments exist in which a significant group decision, leading to an agreed change in social habits, has been shown to be particularly potent. By placing a problem leading to the need for change fully before groups of individuals with informal leadership rôles in a community Lewin [2] was able to show the success of this method of bringing about change in food habits—an intimate and difficult matter—as contrasted with the usual publicity techniques.

The significance of these experiments is that they supply scientific support for the point of view which suggests that the ultimate consumer of any change—whether it be in the field of education, industrial practice, household practice or the application of safety devices—is most readily influenced when he has been a participant member in the process by which discussion of the need for change was initiated and agreed decisions to change were taken.

(*d*) In view of some of the discussion in the first session of this conference concerning the effects of improvement in the physical working environment on productivity, it may be important to draw attention to one of the most obvious findings of the well-known Hawthorne experiments (Mayo).[3] In these, it will be remembered, an experimental and a control group of electrical assembly workers were carefully studied over a period of time. Various changes were then introduced in the physical conditions of the experimental group. Unexpectedly, a rise in

[1] Bion, W. R. and Rickman, J., ' Intra-Group Tensions in Therapy : Their Study as a Task of the Group,' *Lancet*, Nov. 1943.

[2] Lewin, Kurt, Washington, D.C., Committee on Food Habits, *Nat. Res. Coun.*, June 1942.

[3] Elton Mayo, *The Human Problems of an Industrial Civilisation*, 1945, Harvard University, Div. of Research, Mass. ; *The Social Problems of an Industrial Civilisation*, 1945, Harvard University, Div. of Research, Mass.

production took place both in the experimental group and in the control group, although in the latter no changes in physical environment had taken place. Secondly, when the improved conditions in the experimental group were removed and they reverted to conditions similar to those with which they had started, production did not fall to its initial level but continued at the new high level. The important conclusion is that the feeling that somebody was interested in them proved to be as significant in increasing production of these workers as the changes in physical environment and working conditions. It must, however, be pointed out that a finding of this kind depends on the existence of tension between management and workers, although it may be said that such tensions are so universal that one might risk in this field a generalisation such as that just made. It is not altogether irrelevant to point out that in the Hawthorne factory it did not prove possible to develop, at managerial level, the implications of the investigations made there, and that serious strikes in that factory were reported only a few years after the investigation was completed. It can therefore be repeated that the application of research findings without reference to the total field situation is unlikely to lead to adequate results.

3. Current problems.

It may be of interest to indicate the bearing of the last two sections on some current problems of industrial morale and production.

(*a*) *Difficulties over joint consultation.* If we accept the hypothesis that adaptive social change is most effectively introduced with the full participation of those who have to make that change, it will be seen that some difficulties of joint consultation may well have arisen because change has been imposed from above rather than allowed to emerge from full discussion between the various groups in a firm, leading to an agreed decision to operate joint consultation. It is no more possible to bring about participant relationships or an agreed democratic process by autocratic method alone than it is possible to initiate any other change in human relationships by this method. Human beings cannot be ordered to feel differently about each other. Secondly, the effect of introducing a new practice such as joint consultation is likely to vary very considerably with the total situation in the firm concerned. Where there is a low morale setting in which the absence of joint consultation is thought to be a ' deterrent,' in practice the introduction of even what are generally agreed to be the best joint consultation procedures is likely initially to provide no more than a new opportunity for ' scapegoating.' This type of situation needs special constructive effort and ' working through ' before any improvement in morale can take place.

Thirdly, it is common for the significant factors preventing the adequate development of joint consultation practice to be hidden by lack of attention to the ' emotional content ' and concentration of interest on the ' intellectual content ' of committee meetings. In works council meetings, inadequate attention is often given to what might be called the ' music '—the emotional atmosphere. In such groups, there is often an obvious discrepancy between the ' words ' (the verbal content) and the ' music ' (the interplay of mood and feelings). The development of adequate inter-group relationships within the works council is unlikely to be possible unless attention is drawn to this discrepancy ; and the rôle of the social scientist in such matters may sometimes be to help build up an atmosphere in which the significant factors preventing the development of an adequate morale in a joint consultation group may be ventilated and minimised.

(*b*) *Misinterpretation of group behaviour.* Many difficulties appear to arise through the interpretation of group behaviour on the basis of inadequate concepts or within an inadequate frame of reference. In any industrial concern it is usual for management, line executives, technical specialists, office workers, supervisors, and workers on the bench and the floor to find the reasons for their discontents and difficulties in the behaviour of one or all of the *other* groups. Management, for example, often find the seat of production difficulties in the behaviour of supervisors and workers and, in consequence, not infrequently suggest that the absence of a fear of unemployment is an important factor in lowering production. On this, it need only be remarked that the limitations of fear as a motivation of human life should, by now, be well enough known, at least in scientific circles, to show the inadequacy of this point of view. The basis of this over-estimate of fear, however, does not lie in any factual foundation, but in the attraction of this view as a means of evading the real issues which are not only complex but in the end often concern oneself.

More constructively, management often feels that supervisors represent the key problem of production and that training of supervisors may remove an important deterrent to production. This view—not unreasonably—seldom receives the unanimous agreement of supervisors, for they, in their turn, feel that workers and management are

the groups within which the real problems lie. Equally, it must be said that workers will, as a rule, explain their problems or their difficulties even in responding to a crisis situation, by reference to the other groups within the factory.

It will thus be seen that it is an almost universal feature of industrial concerns that reciprocal scapegoating systems have been developed, and they are often heavily sanctioned on what is alleged to be a basis of experience. It may be wise to remark in passing that such systems are not confined to the industrial world but are a universal human phenomenon.

It is, of course, simplest to maintain that the other fellow is the cause of all the trouble, if you have never seen him or met him under any conditions in which this theory may be tested; and it could hardly be said that recreational and social events—which are in many firms the only occasion on which mixing of all the groups in the factory takes place—represent occasions in which freedom of discussion of important matters is at all practicable. For this reason, many firms arrange to hold, outside the factory, week-end conferences of a large and representative section of the firm.

The current industrial picture is, however, not all black; for behind the mutual scapegoating systems there also exist within a firm and its sub-groups the need for good relations. There is, for example, the anxiety of management to be thought well of which so often lies behind a layer of insecure and protective toughness and on occasion shows up as a desire to know 'what the workers really think of management.' Similarly, behind the envy and resentment which shop workers often have of the white-collar office staff there often lies a real desire to work in a community in which these enormous social gaps and their mutual hostilities do not exist. It is often in part a desire to feel 'on a level' with the white-collar worker which leads those engaged on dangerous jobs or dirty jobs to emphasise that the office staff and specialist personnel are not the real 'producers' in the factory. Those who work with their hands seldom appear to realise what feelings of inferiority and frustration may be behind the label of 'non-productive workers'; for the type of job where danger is faced or where things are made or mended offers a more obvious type of satisfaction than that of the less direct activity and contribution of 'staff' departments to the general purposes of a firm.

A long list could be made of different industrial sub-groups between whom tensions can be seen to exist in industrial life—skilled and unskilled workers; weekly paid and salaried workers; union and non-union workers; and there are often corresponding difficulties between the separate departments of a particular factory. Within the intermediate line-management group these problems are coloured by the rivalry situation with regard to authority and responsibility, and over the possibility of promotion. One difficulty here lies in arranging to deal with the internal relations of this intermediate group since supervisors and line management are seldom adequately represented in joint consultation procedure, and usually have to stand on one side to watch management and workers fight out problems which concern their own group to an equal extent.

(c) *Financial 'incentives.'* The many meanings of this phrase cannot be discussed here. Where the 'absence of financial incentive' has been held to be a 'deterrent,' the introduction of piece rates may have very different results depending on the total situation and, in particular, on what may be called the morale of the group concerned. Where the situation is described as one of low morale, the usual effect of replacing the 'deterrent' of a time-rate by a piece-rate is not to improve morale and production but to displace existing discontent in the group on to those concerned with rate fixing. As a result, it is not uncommon to find that any benefit which may have been achieved is dissipated in increased cost of the administrative machinery necessary to handle the tensions and disputes of a piece-rate scheme.

(d) *Inappropriate transfer of problem 'solutions.'* If studying newspapers is any guide, it may be suggested that in the building trade the drive to introduce piece-rates and the employers' drive towards a free market rather than fixed contracts are difficult to understand in terms of the 'financial incentives' but easier to understand if we assume that the insecurity of the building industry as a whole has led to the widespread use of defensive restrictive practice both among employers and employed. In a situation of this kind the introduction of what appear to be financial incentives represents, at least in part, an attempt to balance out insecurity and defensive practices by the introduction of a disturbing factor in a stalemate situation. Difficulties sometimes arise where attempts are made to transfer what appear to be effective solutions of a problem from one setting to another, i.e. attempt is made, as it were, to transplant plants rather than to employ general principles of horticulture in a new setting.

The attempts to transfer a wages policy which has been successful in one firm into a different setting in another firm have sometimes led to a disastrous failure since the

policy has not, as it were, grown up in the new setting to which it has now been transferred.

(e) *Morale factors in production.* Finally, it may be said that many of the attempts to make comparative studies on productivity are seriously affected by the large group of uncontrolled, and sometimes disregarded, variables in the field of morale. These variables can often be seen clearly to represent a main factor in understanding differences in production levels, as in certain instances where firms making the same product on approximately the same methods with apparently similar employees show differences in productivity to the order of three hundred per cent.

4. Applied social science and social change.

Scientific data with regard to different factors affecting production are very scarce ; and research in this field has suffered enormously from partial approaches, whether by psychologists, economists or production engineers. If the general thesis mentioned earlier is accepted—concerning the importance of a total approach—then it can be said that the way is open by which adequate data can be obtained, on which valid generalizations may be based. There are, however, a number of important points with regard to the application of scientific method in relation to human affairs. Most scientific workers now accept the idea of the unity of science, i.e. that science represents not a group of subjects, but a group of methods by which problems may be examined. In the application of scientific method to human affairs, however, an important question of human relationships arises. In the field of physics, the effect of the observer on the field has been clearly recognised and can either be allowed for or overcome in a variety of ways. On the other hand, the study of human beings and human groups presents at least one fundamental difference from the study of inanimate nature. In relation to human problems it is often possible to employ, or deploy, scientific method only when the relationship between the observer and the group to be observed has developed in a certain direction. It may be foolish to suggest that one should ever hope to be able to ask a casual passer-by if one might open his abdomen in the interests of science ; but much social science is based exactly on this pattern.

There is good reason to believe that only when a collaborative relationship—by which is meant something more fundamental than a good personal relationship—has been achieved will it be possible to obtain access to significant and important areas of the human mind or the really important aspects of the psychological life of groups. One research pattern which has shown some signs of being successful is to some extent homologous to that which exists within some relationships between patient and doctor. Once this relationship of the individual or group with a need or a problem and a skilled professional person with therapeutic potentialities has been achieved, it is possible, within that relationship, to deploy scientific method without the risk of obtaining completely inadequate data. This therapeutic approach does not exclude the other types of investigation—the laboratory model, the diagnostic survey, or the use of participant-observer rôles—but where a complete investigation of the main factors in a problem situation is required (and this is generally the case in practical issues) it is difficult to see how any other approach can overcome the difficulties inseparable from the study of the significant factors in human relations.

But even when full understanding of a problem of industrial morale and production has been achieved there remains the problem of bringing about a change in the desired direction ; and here scientific work often appears to be handicapped by an over-close adherence to the naive rationalism which often characterised nineteenth-century scientific thought. The fact that some change is obviously desirable and that means of bringing this about are known, does not of itself guarantee that the change will occur any more than reading a book about psychology or psychotherapy will necessarily lead to alleviation of the emotional problems of an individual. Bringing about industrial change by the removal of deterrent factors is not merely a matter of elucidating these factors and then removing them. It will be necessary to have regard to the total situation and to inaugurate a slow process of change by a continuation of the therapeutic approach within which a diagnosis of the problem was possible.

There is even a further difficulty : where industrial morale and production have been successfully altered in a desired direction, it is important that such actions should be available as demonstration models to arouse the interest of others in tackling problems by similar methods ; but there is here again a difficulty. The tendency is for one firm to copy another firm who appear to have solved a particular problem (e.g. a morale issue, improved by new promotion methods) without a full consideration of whether they are not attempting to transplant a solution from one problem to another without that initial full investigation of the setting of the problem which alone will determine whether this

particular solution is adequate in a different situation.

All of this may seem elementary and rather removed from the practical issues of everyday life; but the point of view and the difficulties which have just been expressed do not in any way support a pessimistic attitude over effective action in industrial morale problems. Although our available knowledge may only exist at what is no more than a rule-of-thumb clinical level, rather than that of validated scientific generalization, it does not follow that such knowledge may not be of great significance, particularly in a crisis situation; but there is certainly a danger that scientific method may be discredited in human affairs because it is inadequately applied. Finally, to say that not enough is known in the scientific sense about industrial problems is a justification for practical research and not for inactivity.

Summing-up
by
Mr. Alec Rodger

I propose to do two things. First, to comment briefly on what seemed to me to be the main points in some of the contributions we have had to-day. Secondly, to tackle with equal brevity the question, Where do we, as scientists, go from here?

Professor Lane, in introducing the discussion on working conditions, dealt chiefly with the influence of those conditions on occupational health, and in doing so he very properly stressed the value of the doctor's part in studying and improving them. He emphasised particularly the rôle of the industrial medical officer as an apostle of preventive medicine. That was admirable. But on one point I found myself perplexed. Dr. Lane advocated team-work in this field, with management leading and balancing the teams. I felt that in the investigation of the problems he described, in the way he described, both the leading and the balancing were more likely to be done by the doctor. Indeed, that seemed to be a clear implication of one of his last points, when he appeared to suggest for the industrial medical officer the function of a sort of 'super'-adviser to management on the conflicting claims of other experts, including production engineers and personnel officers.

That worried me, I must confess. I hope the stage is not being set for another of these wretched battles of prestige. Surely we must agree that the functions of the members of such teams are better settled by the quality of the individuals concerned than by their professional labels. If Dr. Lane and his opposite numbers in other universities are able to recruit doctors of the kind they obviously want, they will soon find them performing the duties he has mapped out for them. If they cannot, they will not; nor should they.

For me, the chief interest of the contribution of Dr. Cope, Mr. Weston and Dr. Bedford lay in their convincing demonstration that, in at least some parts of the field we have been discussing, a very great deal has already been accomplished by orthodox scientific procedures. But like Dr. Wilson I frequently found myself asking, as I listened to them, What about Hawthorne? They said very little about the multitude of psychological problems inevitably thrown up in the study of physical environmental conditions. Why should not their researches have been used more extensively to provide starting points for investigations of an essentially psychological kind? I am not blaming Dr. Cope, Mr. Weston and Dr. Bedford for not having done the job themselves, but I suspect that the relative neglect of these psychological problems has been partly to blame for the fact that their work has not made all the impact it should have made.

When controlled experiment shows that new conditions A produce greater efficiency and greater comfort than old conditions B, are steps usually taken to see what happens when the new conditions A are *replaced* by the old conditions B? Those of you who are familiar with the Hawthorne experiments will see what I am driving at. I suggest that in investigations of this kind, and other kinds, we should *normally* seek to compare the effects of new conditions and old conditions with the effects of what I will call *reinstated* old conditions. If we find (as we often must) that the reinstated old conditions produce substantially better results than the old, we cannot reasonably claim that any improvement the new conditions showed over the old are due merely to better lighting, or heating, or ventilation, or whatever it is.

I was glad Dr. Tredgold's introductory contribution to this second session, on 'human relations,' stressed the fact that we are not the first people to give attention to this matter. Current literature dealing with it is littered with papers which could never have been written if the authors had been humble enough to study the moral philosophers of past centuries. Thoughtful discussion of human rights and privileges, duties and responsibilities was their everyday meat; and we have much to learn from them in our present-day consideration of the problems of human relations in industry.

Mr. Chapman made so many points that I hardly know which to pick out for comment.

His main contentions seemed to me to be two. First, that we must, after all, regard financial incentives as very important, but we must see that our payment schemes are reasonably simple and intelligible. Secondly, that while the planning of methods of payment can now be regarded as a well-developed skill, we have yet to master the social processes necessary to secure their adoption by workers and management. I am sure he is right. While he was telling us about a scheme which involved some rather elaborate calculations of percentages, I was reflecting on the fact (revealed by work carried out in the Services during the last few years) that it is very unlikely that more than half the working population could explain just what was meant by the exhortations we have had recently to produce ' 10 per cent. more.' It seems that there are literally millions of adults in this country to whom the word ' percentage ' does not, in practice, mean a thing.

If Mr. Chapman's emphasis was on the continuing importance of the pay-packet, Dr. Wilson's was on the importance of group membership. He speaks so fluently, so provocatively, yet so appealingly, that when I have been listening to him I always want to go away into a corner to think it all out before I reach my conclusions about it. However, I cannot do that now, and I propose to take the hazardous step of trying to summarise the main doctrine he has been preaching to us.

People, Dr. Wilson tells us, don't always work as hard as they could. The cause often lies in the bad morale of *groups*. We must therefore investigate factors affecting the morale of the *whole* of a group, and its subgroups, as well as factors affecting the morale of the individuals concerned. We can't do this satisfactorily by conventional scientific procedures, by ordinary observation and experiment. We must develop a close relationship with the group. This relationship must be more than a very friendly one ; it must be therapeutic. In fact, only through a healing approach can diagnosis be properly effected.

If we pursue this aim, by this method, what do we find ? Dr. Wilson says one of our discoveries will be that workers in groups have spontaneous co-operative tendencies, which are often denied expression. Another will be that there exists in industry—and outside it—an almost universal system of ' blaming the other fellow.' This leads every group—managements, line executives, technicians, office workers, supervisors, workers at the bench and on the floor—to find the causes of their own discontents in the behaviour of *other* groups.

However, most groups contain within themselves sufficient resources to enable them to meet the difficulties thus created. These self-healing resources can be released through free discussion and by the example of management. This fact leads Dr. Wilson to strong advocacy of the abandonment of autocratic practice and its replacement by honest co-operation.

If I have represented Dr. Wilson's views correctly, then it seems to me that he has provided us with much material for discussion, if only because of his revolutionary attitude to the problem of diagnosis. I personally want to know more about this, and particularly I want to know why Dr. Wilson and his colleagues are convinced that ordinary scientific procedures cannot cope with the investigation of the problems we have been discussing. I am not necessarily saying that they *can*. I am anxious to know why he thinks they *can't*.

Now let me come to my second task. Where do we, as scientists, go from here ? Among the many things we could and should do, there are seven I want to urge particularly.

First, that we should recognise the present importance of short-term research, designed to solve pressing practical problems. Those of us whose taste is chiefly for ' fundamental ' research must, for a time, be prepared either to leave our academic cloisters for the field or to open our laboratories for what are essentially technological studies.

Second, that we should readily participate in the co-ordination of our investigations by recognised and accepted groups of experts, who would ' vet ' our researches and ask, about each, What problem is this meant to solve ? How important is it that it *should* be solved ? Is this the best way of solving it ? Such co-ordination would involve much more than greater friendliness between research teams, much more than adding names to the distribution lists on our reports : it would involve real dove-tailing and, probably, some curtailment of our freedom.

Third, that with the aid of the statistician we should make more determined use of ordinary observational and experimental methods of enquiry. The aid of the statistician is indispensable in researches which necessitate the consideration of many variables, as all ours do.

Fourth, that we should learn to communicate our findings more satisfactorily to those they concern : and that means everybody, from politicians and senior civil servants to workers on the shop-floor. We must employ simpler language, and help it out with straightforward pictorial representations of our data instead of columns of figures. In putting our results across, we should make

far more use of journalists with a scientific bent and scientists with a journalistic bent.

Fifth, that we should take more pains to let our function as scientists be more adequately understood. This is especially necessary for those of us who are psychologists. And I would add here that there is a tremendous need for careful study of resistances to the improved techniques we help to forge. These resistances are of course just as common among managers as among workpeople, though we hear very little of the resistances created by the former.

Sixth, that we should constantly strive to acquire more knowledge of the problems of the managers and others we advise, not only because such knowledge will make our advice more sensible but also because it will make us more acceptable. We may reasonably ask that, in return, managers should show greater understanding of scientific method. (I say scientific method rather than science.) We must teach them not to generalise on too few cases, and we must teach them to appreciate the multiplicity of the factors which may produce any given event. Above all, we must teach them that an ' experiment ' is something more than the mere dropping of an existing procedure in favour of a new one, with a vague understanding that after a time somebody, anybody, will report his general impression of the relative merits of the two.

There are many other points I would emphasise if I had time, including our need for taking more account of past investigations relevant to our own ; for developing better criteria for judging the value of our ' improved ' techniques ; and for providing better training for our research workers.

These I must pass by, on my way to my seventh and last point. We should work to a comprehensive plan, and within a comprehensive framework. Those of us who call ourselves industrial psychologists are inclined nowadays to group our problems under two main headings, ' fitting the man to the job ' and ' fitting the job to the man.' Under the first we help to tackle the improvement of methods of vocational guidance, personnel selection, and occupational training. Under the second we help to tackle the improvement of methods of work, design and lay-out of working equipment, and working conditions (both physical and psychological). The use of a ' map ' of this kind goes some way towards ensuring that, in our approach to problems of productivity, we do not become lopsided or unmindful of the multiplicity of the factors influencing occupational efficiency and contentment. Also, it helps us to arrange our priorities.

I suggest that, when next the Division arranges a conference on the problems we have been discussing to-day, an attempt should be made to see whether we cannot take in the whole field, in one broad sweep, even if we do it only by having short progress reports by speakers representative of the fields covered by the headings and subheadings I have mentioned.

It is regretted that space does not allow a report of the remarks of all who took part in the spontaneous discussion and it would be invidious to select, but the following may be added in conclusion. At the outset Sir Henry Tizard said that the survival of our great industrial nation depended upon the health of industry. This in turn depended on technical factors and human needs : both raised problems which must be overcome, but the latter was by far the more difficult. At the end Sir George Schuster said he had come to the conclusion that we should fail if we approached these problems as people merely seeking a means to an end (productivity). In his view employment in industry should be regarded as an end in itself : it should be an essential part of all that goes to make a good life in the highest sense. If this could be achieved full productivity would follow.

The Chairmen and Speakers

SIR HENRY TIZARD, K.C.B., F.R.S.—President of the British Association, Chairman of the Advisory Council on Scientific Policy

SIR GEORGE SCHUSTER, K.C.M.G., C.B.E.—Chairman of the Industrial Productivity Committee's Panel on Human Factors

PROF. R. E. LANE, F.R.C.P.—Professor of Industrial Health, Manchester University

DR. C. L. COPE, F.R.C.P.—Director of Research into Human Problems, National Coal Board

MR. H. C. WESTON—Industrial Health Research Board

DR. T. BEDFORD—Industrial Health Research Board

DR. R. F. TREDGOLD—Roffey Park Rehabilitation Centre

MR. D. CHAPMAN—School of Social Sciences and Administration, Liverpool University

DR. A. T. M. WILSON—Tavistock Institute of Human Relations

MR. ALEC RODGER—Senior Psychologist, Admiralty

INCENTIVES IN INDUSTRY

Report of a Discussion

At the Annual Meeting of the Association in Dundee the Sections of Economics and Psychology held a joint discussion on Incentives in Industry. In this number of *The Advancement of Science* there is a report of a subsequent discussion at Leamington on the wider theme of Human Factors in Industry, including Incentives. The following record of the papers read at Dundee is published now for convenient reference.

The discussion was held on September 2, 1947, in the School of Economics at Dundee and was opened by the Principal of the School, Dr. J. A. Bowie.

Introduction

By Dr. James A. Bowie

The study of incentives has had its own evolution. It may well be that the course which it has taken is due not only to greater insight, but also to the changing nature of incentives themselves. In recent years the approach to the subject has been through factual studies of the work situation, of workers' attitudes and morale. This approach has already yielded interesting results. It is, for instance, becoming apparent that much that we thought of as absolute is only of relative significance. Studies of fatigue, lighting and other working conditions, of piece-work or profit-sharing plans and of what used to be called ' welfare work ' go to show that these are all facets of a general situation, and cannot, in considering their consequences, be detached from their setting.

The Hawthorne investigations in the U.S.A., and the recent work of the National Institute of Industrial Psychology are beginning to throw a new light on the whole problem of incentives. It is known that work satisfaction depends on the existence of the following factors : reasonable remuneration, good working conditions, social recognition or status through function, and membership of an agreeable working group. It would appear that the higher wages become, the less do they bulk in the amalgam of dissatisfaction, though they remain an obvious weapon with which to fight other battles. Good physical working conditions have been extensively studied. We now know the optimum conditions in respect of lighting, heating, ventilation and atmosphere. But psychological conditions would seem to be even more important than physical ones. Various enquiries have been made which seem to indicate that the worker in general gives high importance to such matters as security of employment, good supervision, chances of promotion and so on.

But all these things do not yet get to the root of the matter. The Western Electric research has shown, as has also many sociological studies, that human motivation is very complex. Our knowledge of the basis of human relations is, compared with the natural sciences, in a very primitive state. But we do know that industry is a social system, a system of human relations which influences greatly the behaviour of the individual members. The factory has a formal and also an informal organisation and cannot be ' a happy ship ' unless these two types of structure are adjusted to each other. Moreover, the factory is also a status system and attains a condition of equilibrium only when an accepted pattern of human relations has been built up over a period of time. Co-operation arises out of a constantly recurring pattern of human relations by means of which each learns what to expect from others and how to react to others.

It may well be that the battle for output should not be fought with the weapons of incentives at all—at least, not as commonly conceived. It may be that no system of incentives will work well or permanently within the limits of the present system. What is needed is a sense of participation, a feeling of ego-involvement. These sentiments may not grow in an atmosphere of factory discipline where many workers feel a prison-complex in relation to their work and believe that under private enterprise they work for an enemy class. A new psycho-sociological approach may suggest many new blow-holes for the human spirit. The provision of human satisfaction in work may involve radical changes in factory life. It seems apparent that joint consultation, profit-sharing, pension, provident or other funds are not so much generators of goodwill as devices which cannot succeed unless goodwill be already present. Since 1800 some twenty solutions, some of them recurrent, have been tried, but they do not seem to have been conspicuously successful.

The present need is for research and experiment. Those firms which, like Harry H.

Payne, Ltd., the shoe-repairers of Birmingham, have adopted new procedures should be studied in detail. Analysis and comparison of the results might point the way to a new attack on the whole problem.

Incentives

By Mr. Charles Madge

The use of payment by results and bonus schemes is an attempt to get round the undoubted fact that the majority of workers work less hard than they are physically capable of doing. As usually applied, this type of incentive is used in a very primitive and mechanical way. It is most successful where it is applied by managements who realise that the money factor is only one factor in a complex situation.

The failure to reach optimum levels of work is due to both conscious and unconscious restrictionism. Conscious restrictionism may be an organized go-slow movement, or an informal understanding among a working group, or in a few cases it may be a 'working custom' applying to a whole industry or large section of it, like the miners' stint. Originating in fear of unemployment through over-production, it can only be overcome by gradual re-education. Unconscious restrictionism is a neurotic expression of resentments and frustration felt by the worker in his relation both to his employers and to society as a whole. It can be overcome by the effective reintegration of the worker in society and in the working group.

In thinking about the relative importance of the money incentive, we have to bear in mind all the different things that are interchangeable with money. There is rent paid for housing space, there is the weekly housekeeping bill and there is pocket-money to be spent on tobacco and leisure activities. The commodities thus paid for out of earnings have a definite price which you can see in the shop window. But money can also be exchanged in a less obvious way and at less clearly defined cost, against leisure or against hard work. You may be prepared to 'pay,' in the form of reduced earnings, for the shorter time you spend working and the lessened effort you put into it. You may also temperamentally be willing to 'pay,' by accepting a lower-paid job, for the avoidance of responsibility. On the other side of the picture, you may be prepared to reduce your effective spending-power by taking on the expense of wife and family. The demand for goods must be considered together with the demand for leisure, for having an easier time, for avoiding having to think and for having a family. Some of these demands would be considered socially beneficial. The desire for leisure and the desire for children are, on the whole, to be encouraged. The demand to be allowed to give less than one's best to a job is, on the other hand, largely neurotic and may reflect inner anxiety and unhappiness in those concerned.

This situation is often ignored in current talk about 'incentives,' which has become a mechanistic catchword. Social scientists should concentrate on means of reducing the discomfort and monotony of factory life, as well as the economic insecurity and lack of social integration which has accompanied the rise of industrialism. If they focus their efforts on making the factory worker a happier, more balanced individual, they will in the end do more to increase production than by elaborate bonus schemes. In any case, the main way to increase production is by improvements in machines and in physical factory organisation.

In such industries as mining, heavy engineering, deep-sea fishing and agriculture, it is possible to develop a 'heroic' attitude towards the work. The same holds for the building industry, on any major site. In light engineering and many other industries and occupations, there is ever-increasing monotony and consequent frustration, however benevolent the management and however hygienic the factory. The workers in these industries have to adapt themselves to the inhumanly even tempo of the machine. This sets up a degree of frustration and apathy which spills over from factory life into the whole of social life. It is probably going to be necessary to re-humanize this side of industry by making allowance for human variability and building up occasions for special spurts and drives. In agriculture there is the procession of the seasons, a time for ploughing, a time for sowing, a time for harvest. Something of this sense of drama in time must be restored to the highly mechanized industries if they are to hold the interest of the workers.

Harmony in Working Groups

By Mr. Dennis Chapman

The researches of the Harvard School of Business Administration showed, by careful experiment, the importance of the relations of members of the working group to each other and of operative groups to management. It is interesting to note, however, that many of their findings were anticipated by the excellent observations of Graham Wallas early in the century, but as was perhaps typical in the development of the Social Sciences in England, these observations were not followed up by systematic scientific research.

The problem which waits solution is: What methods of education selection, training and social and industrial organisation can make for harmony within working groups and by what methods can disharmony between working groups be reduced or eliminated?

The solution of some practical problems of this kind is being undertaken by industrial psychologists, sociologists and psychiatrists, but an organised body of knowledge of the principles involved must await the accumulation of a sufficient number of case studies to make valid generalisations possible.

Two examples are given here to show the range of this type of problem. The first is an example of disharmony within the working group, the second an example of disharmony between working groups.

Case A

In a textile factory absenteeism in one department had reached a very high figure; labour turnover was high and there were many vacancies. Investigation showed that a major cause of this was that the foreman who ran the department had established a successful concert party, the principal members of which were drawn from his department. These young members were given a great deal of attention and assistance in their theatrical activities by the foreman and his wife. The records of this group showed that they were very satisfactory employees. They had good records of output, were rarely late, seldom absent and rarely away for minor illnesses. The group of girls in the same department of the same age who were not in the concert party, on the other hand, had less satisfactory records, and were significantly worse than older women in the same department.

The situation in the department was improved when the concert party was reorganised so that no small group in any department was placed in an especially favoured position.

Case B

In Case A the causal factors were obvious and, as the situation was of recent development, secondary factors had not arisen. In this case, that of the weaver-tackler conflict in the cotton industry, the situation has had a century in which to grow and to create a state of affairs which is now a part of the culture of the weaving section of the cotton industry.

The basis of the conflict is the dependence of the weaver upon the services of the tackler who is responsible for the maintenance of his loom. Because of the very subtle craft basis of the tackler's work and a history of able trade union organisation, the tackler has a very independent position in the industry, and very often makes the weaver uncomfortably aware of his power. This power, however, has been challenged successfully by some employers so that there is an underlying feeling of insecurity. These factors have led to the social isolation of the tacklers as a working group within the firm and industry. It has also been responsible for the growth of aggressive humour—the Tackler's Tale—a joke in which the tackler is the butt.

An account of the situation was given with an example to show the extremely devious way in which the secondary effects are worked out.

Information gained from Attitude Surveys

By Mrs. W. Raphael

Attitude surveys have been held with 15,000 workers of all grades in industry from directors to labourers by the staff of the National Institute of Industrial Psychology in recent years. The technique used is that of the individual confidential interview and much information is obtained on the motivating effect of different incentives, and on the chief factors that influence attitude to work. Many of the following factors operate in all grades and types of work.

(1) Financial incentives are not all-important, though they have great significance if the workers do not consider their pay ' reasonable ' or ' fair.'

(2) Satisfaction in the job itself is important among many managerial and skilled workers, less often in unskilled or semi-skilled work. Good vocational guidance, selection and job training may increase such satisfaction.

(3) Participation, the feeling of mattering to the organisation, knowing about its activities and possibly influencing these are important incentives which should be stimulated by such methods as joint consultation (in its widest sense).

(4) Different branches of the same firm often show interesting differences of attitude, usually attributable to the management of these branches. Selection and training of supervision is of paramount importance, and consideration should be given to unofficial leaders found in every concern.

(5) The social environment rather than the content of the work is often valued, especially by women.

(6) Other influences include the social value of the job, the working conditions and hours, etc.

Incentives in the Building Industry

By Miss Norah M. Davis

The investigation described in this paper was carried out in 1946 by the Industrial Health Research Board of the Medical Research Council, at the request of the Ministry of Works. The purpose of the investigation was to obtain information about the operatives' attitude to their work and to working conditions and to ascertain which factors provided the strongest incentives to working. This investigation was intended to be a pilot survey for a later and more detailed study. Interviews were held with 400 operatives, from 14 sites in various parts of England and Scotland, on which traditional brick houses were being built, and all the men were extremely co-operative and frank.

Five broad topics were discussed . . . the job, working conditions, wages, home life and health. The results show that there was a striking degree of homogeneity in the group as to the nature and relative importance of their predominating interests, despite the fact that the group included workers of all types and consisted of individuals of marked and differing personal characteristics. The men tended to regard each aspect of their environment in relation to those interests and to judge that aspect according as to whether it seemed to facilitate or to frustrate their main desires.

One question to which the operatives attached great importance was that of security of employment. Uneasy scepticism about the future made the assurance of greater security and a guaranteed week seem a matter of urgency, and the theme of security kept on emerging throughout the interviews. The most frequent reason given for not wishing their sons to enter the industry was its lack of security ; the main argument against payment by results was preference for a steady wage ; and the resented low social status accorded to the building operative was thought to be due to his being ' casual labour.'

There were widespread complaints that the weekly wage was inadequate to meet the high cost of living. Only one man out of 400 mentioned shortage of consumer goods and no man said that P.A.Y.E. would be a deterrent to attempting to earn more money by working overtime. Discontent about wages was intensified by the relatively higher wages of some other types of industrial workers. However, this strong and widespread desire for more money did not make a system of payment by results acceptable to the majority of the operatives. The main arguments advanced against payment by results were based on fear that such a system would conflict with other strong and pleasurable motives for working, in particular with the motive of working for its own sake. Pride in workmanship was very marked and there was general agreement among the group of men, including the labourers, on the importance attached to quality rather than to quantity. The most frequently mentioned ambition was to become more skilled or to obtain promotion.

Another aspect of working to which the operatives attached great importance, and which they also felt to be menaced by payment by results based on individual work, is that of the social solidarity of the group. The marked good fellowship among the operatives seemed to some extent to be due to the sense of tradition. Although this group loyalty was partly a defence against the ' other side,' the employers, its mainspring seemed to be spontaneous sociability.

The social incentives to work came not only from within the working group but also from the relationship between that group and those in authority. About half the operatives expressed positive liking and respect for their foremen, and the results of this investigation confirm those obtained elsewhere of the greater efficacy of praise than of blame as a spur to activity. On most sites the relationship between the operatives and the management was characterised by lack of contact and ignorance. The management were less popular on the direct labour sites than on the sites of private contractors : one reason for this was possibly that the direct labour sites were larger and the individual had in consequence less feeling of personal responsibility ; the main reason, however, seemed to be the centralisation of authority and the inadequate or circuitous methods of communication between those on different levels.

Many men showed that they were aware of the social responsibility of their work, and there was some resentment at Press and other criticisms of the operatives as lacking in public spirit.

This investigation draws attention to the importance of the non-economic incentives in the building industry. The building industry, because of its history and the nature of the work, differs in many ways from other great industries such as engineering. It has been less affected by mechanisation and the desire for money as a symbol of individual worth. The building operative, despite his past hard times, has maintained his self-respect as a craftsman and as an individual, and is more likely to respond to incentives that appeal to his own scale of values than to those that are transplanted from industries very different from his own.

THE INDUSTRIAL DEVELOPMENT OF DUNDEE

By Sir Garnet Wilson

It is not the intention to present this survey of the industrial development of Dundee under an array of figures, revealing as they may be. That were to invite a form of statistical boredom. The live facts of two and a half decades of the industrial history of Dundee are in themselves a social and human document, the pages of which you are now invited to consider.

At the time when the British Association was preparing to meet in Dundee in 1939, Mr. Kenneth Eastham, of the Dundee School of Economics, was one of those who collaborated in the production of the booklet of scientific information about Dundee and district which was issued to the members. His part was to provide ' an economic survey of present-day Dundee.'

In an introductory paragraph he wrote :

> ' Dundee is a single industry town and the British jute industry is almost wholly located in Dundee. These two facts must form the starting point for any economic or social study of the city. The problems of the jute industry are the problems of Dundee, for not only is that industry the principal employer of labour, but most of the rest of the town gets its living in industries subsidiary to it or by catering for the personal needs of those employed in it.'

When Mr. Eastham was compiling the notes for his paper there were 23,910 insured jute workers in Dundee, or approximately one-third of the total insured population, with 5,203 of these registered as unemployed. The figures of jute workers for the rest of Scotland were 3,680 and 292.

Owing to the predominance of the manufacture of jute in its industrial economy, Dundee has often been described as a one-industry or single-industry town, as Mr. Eastham has described it. The description is only relatively correct ; correct because of the high percentage of jute workers to the total number of the employed : correct, too, because any decline in the industry added heavily to the number of the unemployed. It is now relatively incorrect, because of the reduced percentage of workers employed in jute to the total insured population (24·12 per cent. at July 14, 1947) and by reason of the new industrial development.

The last (the 1939) issue of the Chamber of Commerce Year Book listed 607 individual products of Dundee manufacture, classified in seven major groups, of which confectionery, engineering and shipbuilding, and textile manufacture, including flax, accounted for 426. Miscellaneous manufactures, that group which has added much to the prosperity of such an industrial city as Birmingham, totalled 181. Dundee, therefore, had a variety of manufactures, but not a sufficiently important variety. Accordingly, in the inter-war period the prosperity level was difficult to maintain ; the long record of unemployment was a barrier to progressive endeavour.[1] The population remained static and the industrial pattern unbalanced. Young men of spirit continued to seek fortune in other places and in other lands, probably to a total of from 300 to 500 each year. Neither the facts nor the figures may be wholly material, but, within the 60 years period from 1871 to 1931, 1931 being the last firm figure of population available, the total net migration from Dundee was just over 38,000, which represents nearly a quarter of the mean population over the 60 years. During the same 60 years, Aberdeen's net loss by migration was 10,900, which represents under 8 per cent. of the mean population, so that Aberdeen's rate of loss was about a third of that of Dundee.

Comparing the population of the two rival cities, Dundee increased from 119,000 in 1871 to 176,000 in 1931, while Aberdeen in the same period increased from 88,000 to 167,000. Aberdeen at 187,000 is now 7,000 ahead of Dundee.

Equally irrelevant, but interesting, is the notion of Dundee as a women's town, a title shared by other textile centres. The Parliamentary electoral roll of 1938 showed a majority of women of 15,337, or 13·76 per cent., that of 1946 a majority of 14,960, or 12·8 per cent.

Although it must have contributed in no small degree to the industrial economy of the city, this phenomenon is neither new nor rare. The census of 1871 showed the same disparity of numbers between the sexes, both in Dundee and Aberdeen. The surplus of women in the population of Dundee in 1871 was 15,514, and in 1931, 17,999 ; and of Aderdeen 8,609 in 1871 and 13,536 in 1931.

It is not necessary to recall, however, that Dundee was not alone in Scotland in the trough of depression. The West of Scotland

[1] See Appendix A for record of unemployment in Dundee, 1920–47.

suffered even more severely over a wider field of employment.

For some years before the portents were read and the evidence was stark to the eye, Scotland had allowed herself to become largely a country of staple industries and established businesses, conservative in outlook. Few had contemplated a future when its centre of gravity of industrial activity would move away, leaving Scotland industrially almost an isolated territory.

The lighter forms of engineering were not attracted by the native engineering genius of Scotland, or were perhaps repelled by the perfervid politics of Clydeside ; they were drawn to that industrial agglomerate, the Midlands of England.

Motor engineering in Scotland had failed. The important firm of Stewarts & Lloyds saw fit to desert Coatbridge for Corby. For a long time, the *Queen Mary* rested on the stocks of an almost idle shipyard.

Partial relief came to the West of Scotland in legislation for the depressed areas and a trading estate rose at Hillingdon, on the outskirts of Glasgow, with greater possibilities in its potential than in its actual value to the relief of mass unemployment. More radical treatment was required.

Whether Dundee should seek the protection of such legislation was freely canvassed, but discussions with the Government of the day eventually left Dundee to its own devices and remedies.

The work of a Development Council convened by the Town Council had little success without Government backing, and the project of a small trading estate on the outskirts of the city received scant support.

Throughout those parlous inter-war years, with unemployment taking heavy toll, Dundee as an industrial centre and in popular esteem a most friendly town had always had notable advantages to offer to industry. An ample and well-distributed water supply had few equals in volume and quality. Gas, electricity and transport were all readily available within the compact area of the city. It did not require the war, with its occupational changes, to advertise the adaptability and efficiency of women's work. The city had deserved a greater fame as a centre of industry and commerce.

Whatever may have been the cause, and it lay partly in Government circles and partly in the city itself, there was tardy recognition of Dundee as a centre where war production units might be directed and settled. No shadow factories had been planned before the war.

It was not until early in 1941 that the Government was aroused to consider at one and the same time the needs of the city and its potentialities. There had already been a marked expansion of employment in engineering and shipbuilding and in the demand for jute. War-productive industry had absorbed the first of the young people directed by the Ministry of Labour and National Service to work in other channels. 1,300 young women had gone to the Midlands of England, more than half by voluntary action. The Ministries of Supply and Aircraft Production were in touch with local production, yet, in 1940 unemployment had ranged from a low figure of 6,459 to a high figure of 9,613.

It was a time for serious measures. An approach to the Board of Trade at the end of 1940 was made on the plea of a great opportunity to send to Dundee selected units of munitions production to help relieve the current unemployment and which, by their probable continuance in Dundee after the war, would contribute to future employment and prosperity.

The anxious appeal for Government aid was more than successful, and here is the substantial roll of those for whom the Board of Trade eventually found accommodation in Dundee by the concentration of jute mills and factories, working through a district office opened in the city in July, 1941, when the unemployment roll still stood as high as 5,494—

Ransome & Marles Ltd. :		
Ball bearings, at Edward Street Works and in part of three other works.	Peak employment	2,386
Burndept Ltd. :		
Wireless batteries, at Belmont Works.	Peak employment	852
Hamilton Carhartt Ltd. :		
Makers of protective clothing, in part of Tay Works.	Peak employment	189
A. C. Wickman Ltd. :		
Makers of WEMCO tungsten tools, in part of Tay Works.	Peak employment	439
Briggs Motor Bodies Ltd. :		
Production of jerricans, at Ashton Works.	Peak employment	2,928
	Total peak employment	6,794

The introduction of these new concerns was not completed without many exasperations and delays. By September, 1942, only 442 people were working in the new factories. The sincerity of purpose, however, shown by the Government at this time to Dundee had no better witness than the expenditure sanctioned by the Ministry of Supply to recondition and re-equip Ashton Works for

the urgent production of jerricans. A sum in the neighbourhood of £700,000 was expended, and later justified by the factors of war production : a weekly output of over 100,000 produced by what was in the early weeks almost 'green' labour. When the acme of production was reached, the unit here was believed to be higher than in any similar establishment in the country. The sheet metal used was brought to Dundee across more than half of the country.

While these new adventures were being planned, an approach in London to the Ministers of Labour and Supply was successful in stemming the flow of young women to the Midlands of England, whither at the time in question, as has already been stated, some 1,300 had already gone, 700 voluntarily. The argument was that we ought to provide for the incoming war industries an excellent sample of the female labour available so that some at least of the number might be induced by the quality available to continue after the war to manufacture in Dundee. Burndept, Hamilton Carhartt and Expanded Rubber have actually done so.

The Ministry of Supply was responsible for the introduction of other units : the Expanded Rubber Co., Ltd., worked through the war on Admiralty contracts. Veedip, Ltd., shared with the Expanded Rubber Co. the requisitioned works of the North British Linoleum Co., Ltd., but had to discontinue production of anti-gas rubber gloves shortly after the Japanese invasion of the rubber-producing countries.

In the Taybank Jute Works of the S.C.W.S., Ltd., an interesting and highly skilled introduction was the making of grommets or anti-torpedo nets, and here also the unit of production was high, the work being capably done almost wholly by women, former jute workers.

The war factories in Dundee were uniformly successful. The advantages of work in the city were early discovered ; in particular, the unit of individual production was high, especially where women were employed.

By the end of the war, every industry or branch of industry, new or old, was working on a high level of production. Unemployment had fallen in 1944 to a mean figure of 694. Wage packets had never been so full, nor the city so prosperous. The majority of the young women directed to the productive Midlands of England, or who earlier had gone voluntarily to work there, were back in the city.

Whatever the future, it was early evident that the coming of peace would find the city with a highly trained industrial personnel, skilled in new tools and methods, with an experience of production programmes and efficiency standards. Notwithstanding this measure of industrial success, we had only passed through the first phase of the fight for a prosperous city. No one could look back upon the humiliation of the tragic record of inter-war unemployment and contemplate the gulf between despair and security without taking action. We had to realise that the pulse of happiness in an industrial community like ours was employment.

In 1943 steps had already been taken to consider the whole question of the industrial future of the city.

The Local Employment Committee had then compiled a return showing an estimate of future potential employment based on the pre-war (1938) distribution of industry, every circumstance evident at the time having been carefully weighed and considered. This return showed that, without new opportunities for employment there would be no work for 13,840 people once the expected post-war boom had subsided. The figure was later raised to 13,980. Here then was the base line of opportunity. Without delay there was prepared and submitted to the Board of Trade by the Corporation a memorandum on the post-war position of industry in the city with special reference to past and future problems of unemployment. Here, in a few sentences, are pregnant extracts from the memorandum.

The Jute Industry.

The present war, as well as the last war, has shown the jute industry to be an essential industry in war. As such, therefore, its preservation and prosperity in Dundee should be the immediate concern of the State.

It is unnecessary to labour the advantage that India has over Dundee in wages costs. The United Kingdom has continued up to now to be a free market for the importation of Indian manufactured jute goods and the shipments to this country amount to what might almost be termed dumping, owing to the impossible competitive conditions between Dundee and India. Questions of major policy in the hands of the Government have left the jute industry in Dundee largely to its own devices, which, in the face of the tremendous competition already indicated, have not enabled the industry to provide employment for all its workers.

Post-War Employment Problems—Search for a Solution.

The Corporation holds the view that industry in Dundee can find room for a greater variety of manufacture. The Corporation hopes thus to encourage a wider spread of production and employment.

Present factory premises, when available

for other uses, are not deemed to be suited to the most modern conditions of production. During the past two years many important interests have sought opportunity to manufacture in Dundee but have found the prevailing type of premises unsuitable, in each case preferring a one-floor complete factory unit. The alternative of a trading estate where such modern factory units can be built is, therefore, obvious and practical.

The interest of the small group of engineering employers will be sought so that the wider training and fuller equipment of wartime may be fully utilised in other directions to re-establish engineering in Dundee.

There followed references to a Tay Road Bridge and to a Civil Aerodrome, the latter of which is about to be opened at Errol.

Labour.

The workpeople of Dundee are second to none in industrial skill and aptitude. Dundee-trained mechanics and technicians will be found in responsible posts both at home and abroad. The women workers are used to industrial operations and very high expressions of opinion of their skill have been spontaneously given by employers from the outside who have been drawn to Dundee during war-time.

The concluding paragraphs dealt with the distribution of labour.

The population of Dundee includes a large preponderance of women. Industries favouring woman labour would find in the city an unusually large supply of suitable and adaptable labour. Such industries suited to Dundee are: baking, knitwear, rayon or other textile manufacture, colour printing, plastics manufacture, light engineering (including electrical products), clothing manufacture, extension of the canning industry.

With one exception, these options have been met.

A specialised group of industries was added, viz.: aero engines, motor bus engines and bodies, machine tools—jig and tool-making, precision instruments, agricultural implements—repair and assembly.

Finally, notwithstanding the apparent surplus of female labour, the Corporation is anxious to encourage the introduction of industries capable of giving employment to men as well as women. Under present circumstances, many highly skilled and ambitious young men are forced to find work away from their native city owing to the lack of opportunity and advancement.

The Corporation places on record these facts and figures and represents that the future position of Dundee as an essentially industrial city and the centre in the United Kingdom of an important textile industry has an urgent and pre-eminent claim upon the attention of the Government and in particular upon those in authority whose concern it will be, by measures of reconstruction, to find a cure for mass unemployment.

The memorandum carried the following paragraph upon harbour and dock facilities:

> 'The Harbour Board has approved in principle an ambitious and extensive scheme of Harbour and Dock Development which will re-create the waterside facilities for inward and outward trade and traffic, and provide a new and important Graving Dock.'

The Harbour Board was guided in its deliberations by a most competent report entitled 'Dundee Harbour—Report on Present Condition and Future Works, 1943.' This was presented to the Board on March 2, 1943, by Mr. Norman Matheson, General Manager and Engineer. The suggested provision of a modern graving dock, urged for a long time by the Caledon Shipbuilding and Engineering Company, will, when completed, add a new chapter to the Company's records.

At a later stage of the war, the jute industry, in common with other textile industries, was invited to compose and present to the President of the Board of Trade a survey of conditions in the industry and to have regard to future problems. This report set forth at some length and in detail the views of the industry on the grave difficulties under which it had been compelled to work against increasing Indian competition. The positive items of the report clearly sought to indicate the vitality of the industry.

Whatever discussions took place at Cabinet level, Dundee was scheduled as a Development Area under the Distribution of Industry Act, 1945, and notable advantages have since accrued to the city. An industrial estate of 90 acres and planned to accommodate 10 standard factories, each of 100,000 square feet, has been opened to the north-west of the city. The first standard factory on the site was one of five allocated to Scotland during the later war period and is now occupied by Expanded Rubber Co., Ltd., one of Dundee's war-time industrial guests, and by B.X. Plastics, Ltd. The ninth of the factories is now under construction (August 1947).

The fortunate purchase by the Corporation of that part of the estate of Camperdown immediately adjacent to the city, and now within its boundaries, enabled the provision of factory sites to the National Cash Register Co., Ltd., the well-known American company manufacturing business and accounting

machines, surely one of the finest factory sites in the country, and to the U.K. Time Co., Ltd., makers of clocks and watches. Both these factories in external lay-out and internal planning have followed the most modern standards of architecture, health and welfare.

The assembly lines of the Cash Register factory have already turned out hundreds of their cash and accounting machines, while U.K. Time wrist watches, made in Dundee, are on sale and in active demand.

The London business of L. S. Mayer & Co., Ltd., was amongst the first of the newcomers to acquire premises in Dundee, and they are making here clocks, handbags and powder compacts, specialities in which continental enterprise formerly excelled. Logan coal-cutting machines, Dundee-built, will help increase coal-production.

From Luton has come the firm of Hart Ashworth to occupy one of the standard factories on the industrial estate for the manufacture of felt and felt hoods for ladies' hats. The 'Made in Dundee' label will soon be prominent in the world of women's wear.

Nor do these welcome arrivals in the industrial family nearly exhaust the list.

One other development must be mentioned: Courtaulds, Ltd., plan to settle a factory 13 miles to the north-east of Dundee on the nearest convenient site where effluent may be allowed to flow into tidal water.

The Corporation, too, in its own town-planning arrangements, set apart various areas to the north-east of the city, served like the estate on the north-west by the arterial Kingsway. Here, the important local firm of Bonar Long & Co., engaged in the production of electrical transformers, are doubling space and capacity, and the new firm of Smith & Lomax have opened their light engineering business. Here also a Ministry of Labour Disabled Persons Training Centre was to have been opened on a 7-acre site, but the factory, when constructed, will now be occupied by two important firms, employing male labour in the production of goods of unique importance.

The measure of these achievements is a triumph of co-operation between Corporation and Government, Members of Parliament and Ministry officials. No city in economic distress could have been better served than was Dundee at this time. The results are plain for all to see.

Local industry has not failed to answer the challenge of the future in a world of intensified competition. Secure in the possession of managerial staffs equal to those in any other branch of the textile industry, and in the knowledge that, by 1939, 89 per cent. of its yarn production had been turned out by the most modern machinery, the jute industry has gone ahead with plans for a new economy intended to provide a higher wage level for all engaged in the manufacture of jute.

With a reflection of the practical genius of those who first planned and carried out the manufacture of jute in Dundee, the men in the industry to-day are determined that nothing shall be left undone to restore full prosperity to its various branches, whatever difficulties may lie ahead.

Not content with the efficiencies of 1939, some of the leading firms are carrying out large-scale installations of the latest machinery, in some cases necessitating the scrapping of what in 1939 was modern machinery and involving substantial reconstruction of present buildings.

In weaving, loom developments are receiving close attention. An automatic cop changer of German invention, reported on by the jute trade delegation that visited Germany, is being installed in a number of establishments. Experiments, too, are proceeding with a British high-speed loom that has a stationary lay. Great interest also was shown in a film demonstration of a novel circular weaving loom of French invention.

Urquhart Lindsay and Robertson Orchar, Ltd., makers in Dundee of jute machinery, have opened in part of their works a practical demonstration and experimental mill, equipped with the most up-to-date preparing and spinning machinery of their manufacture.

A Jute Research Association has been organised, and schemes of training and other plans of efficiency of production and marketing applied in advance of any report the Working Party on the Jute Industry may make. The training and introduction of male spinners in the industry is one of many developments. 'Fibro' is being spun, and from the yarn entirely new fabrics produced for the clothing, upholstery and carpet trades.

Among local enterprises, these may be noted. Two firms of international reputation are extending operations in new factories: Keillers Ltd., in bakery products and confectionery, and Valentine & Sons, Ltd., in colour printing and allied products, with new employment for 480 and 210 workers respectively. J. K. Mearns & Co., Ltd., plan to extend the manufacture of women's and children's clothing in a new factory on the industrial estate, enrolling 216 new workers. Lawside Engineering Works will employ 210 men; British Fish Canners, 100 women.

Light engineering, also, has found a fuller and welcome place among us.

The industrial pattern of the city is becoming more varied and colourful and better balanced. There will be a greater spread

of manufacture. Opportunities for young men have been found, in particular by the newcomers to the industrial family. The target figure of employment at the Cash Register factory will be predominantly male, a tribute to the quality of those already engaged. Thus, the industrial blood-letting of the past generation will soon be stopped, although the lure of the sea will continue to attract youth and recruit for marine engineering an annual quota of young men who have completed beforehand an active engineering apprenticeship. At the moment, Colonies continue to draw families and single individuals to their far fields and opportunities, the war and its interchange being largely responsible.

Two employment problems will arise in the future: How far can the challenge of better factory lay-out and working conditions be met by those establishments in the older areas where, hemmed in by other buildings, expansion is always difficult and often impossible? While present capital costs are high—it were idle to expect any complete reconstruction, but measured progress will be made: is, in fact, already being made.

Apart from the cost, economic production will demand the most efficient lay-out in every industrial unit, and modern standards impose the optimum of comfort and well-being for all engaged in industry.

The other problem is one of labour: How far will the presence of new and varying kinds of work and employment attract workers away from present occupation, even if a change will involve daily travel to the outskirts of the city? Experience alone will provide an answer. There are many considerations to be weighed. A hosiery factory in Liverpool has found that it can draw girls across the city provided the journey does not involve a change of conveyance in the course of their journey from home to work. There will always be a tendency on the part of many, especially married women, to endeavour to find employment as near home as possible. The neighbourhood factory is regarded almost as a second home: certainly as a familiar milieu.

Dundee's register of unemployment for week ending July 28, 1947, was men 1,774; women 354; boys and girls 25; a total of 2,153. The number has fallen from an early post-war peak of 3,592, a figure low compared with the devastating totals of the inter-war period. Of returning service personnel 96 per cent. have been re-absorbed or provided with other employment.

The question may be asked whether it will be possible, without drawing on a widening hinterland around the city, to meet the need of every single business for workers, skilled and unskilled, male and female? The conservation of the labour force and the efficient use of labour, the machine, paramount in the modern economy of industry, making its growing contribution, are not local problems but national perplexities. They lie at the root of the Government's present concern over production, and the virtue, if such it can be called, of making-do is likely to be thrust upon many business executives throughout the country as a dire necessity. The experience of doing without the young people continuing at school for that extra year may contribute something to the solution of the larger problem.

A city prosperous and industrially important will always attract the incomer; what Birmingham and other successful industrial cities have done, Dundee can do. Given an eventual adequate supply of houses and with the young men feeling the pulse of happiness in their native city in steady and lucrative employment, Dundee will grow: in fifteen years the present population of around 180,000 should advance to 200,000. There are those who are sanguine enough to see within a generation in Dundee a population of 250,000 well employed and happy and content with the efforts of the past that have contributed to their well-being. They see the new Dundee, grown beyond its present size, its place clearly marked in every gazeteer of world trade.

The Government publication on *Industry and Employment in Scotland*, better known as the Scottish White Paper, concludes its observations thus: 'Undoubtedly there is a considerable way to go before Scotland's economy is on an entirely sound basis. The evil effects of twenty years lack of planning in Great Britain as a whole at a time when many new industries were developing are not quickly remediable. Sufficient progress has been made in securing projects for new industries in Scotland to give real grounds for hope in the future. But a sustained effort on the part of all sections of the community is needed in order to overcome, as quickly as possible, current shortages of materials and supplies which limit production and necessary expansion of industry. Scotland needs, even more than the rest of the country, to win the battle for output.'

The industrial city of Dundee is already in harness.

[*Paper read to the Economics Section at Dundee on September* 2, 1947.]

VILLAGE PLANNING IN SCOTLAND, 1745–1845

By J. M. HOUSTON

THERE is a striking contrast between the highly developed village institutions of the English manor village and the lack of such development in the Scottish Lowlands. Indeed the very name 'village' is alien to Scotland and definition of the term can only be arbitrary. The English farm village is not found in Scotland since rural organisation there has not enjoyed the same traditions and developments. The preservation of the old English village system is the basis for an improved community life as envisaged by the Scott Report, but in most parts of Scotland, a system of this kind has still to be built up almost from the beginning. Therefore there is a need in Scottish country planning to investigate its peculiar problems and suggest proposals in the light of the historical background. The planning of villages has already taken place in Scotland, especially in the century after 1745, so that we can learn from experience.

The distinctive features of the rural settlements of Scotland, the fermtouns, kirktouns, castletouns, etc., are largely due to the different background of land and burghal legislation, and social organisation from those of England. The exclusive marketing monopolies of the Scottish Royal Burghs until the sixteenth century, are largely responsible for the lack of marked villages until the end of the eighteenth century and for the belated development of her rural industries. The baronial markets established on estates during the sixteenth century and later were often little more than hamlets performing burghal functions. Not until after the '45 with the general economic and social awakening of Scotland, were villages seriously developed, and in the century that followed, they were designed and built as planned units in many parts.

While the fortunes of village life in England during the eighteenth and early nineteenth centuries were largely associated with agricultural developments, the building of villages in Scotland was, of necessity, related to rural industry and trade. Economic changes in Scotland showed the need of village society to stimulate industry and trade in areas where an unfavourable environment necessitated employment supplementary to agriculture. Moreover, it became essential to erect villages in order to absorb the surplus rural population that resulted from the revolutionary changes in agricultural management. In large measure therefore, the fortunes of Scottish villages, outwith the coalfields, were related to the rise and fall of hand-loom weaving of woollens, the mechanisation of the cotton industry and the general increase and decline of rural trade.

Written accounts of village planning during the century after 1745 are largely found in the Old and New Statistical Accounts, published in 1791–99 and 1845, while population data for villages are particularly detailed in the 1841 Census. On the basis of these sources, together with parochial histories and topographical dictionaries, it has been possible to construct a graph which indicates the foundation of over 150 planned villages, excluding coal-mining and urban developments, divided according to their origin and function.

The period 1745 to 1770, particularly after 1750, shows the predominance of agricultural activities in the erection of 'tradesmen' and 'estate' villages, associated with the improvements of private estates. These were facilitated by favourable agrarian legislation, especially for private enclosure, and the monetary compensations granted after the abolition of heritable jurisdiction in 1747. Village erection reached its peak in the following period, 1770 to 1795, due partly to the rapid growth of the cotton, flax and woollen industries. Agricultural improvements and industrial developments together accounted for the building of over fifty villages, mostly in the Lowlands. The periods 1795–1820 and 1820–1845, are more closely associated with the erection of settlements in the Highlands. The later enclosure movement in the Highlands and Isles and the social implications of its agricultural changes and clearances for sheep farming accounted for the erection of villages founded from about 1790 until the middle of the nineteenth century.

Throughout Scotland, the distribution and types of these villages was essentially related to the geographic framework and historic phase in each region. The villages in the west were mostly associated with cotton spinning and weaving, readily accepted because of the supplementary needs of a region whose climate made it difficult to live a self-sufficient community life by tillage alone. Large baronial estates interlocked with numerous small 'yeoman' farms, especially in Ayrshire, offered satisfactory conditions for capital and labour, particularly cottar and female employees, required for country manufacturers. The expansion of the cotton industry from Renfrewshire and Ayrshire in the late eighteenth century was, therefore, largely responsible for the rapid and widespread erection of villages from Galloway to Perthshire; that is, wherever water power, suitable labour and communications were available. Independent of the surrounding countryside for their markets, these isolated 'factory' villages, housing an industrial population in rural surroundings, were supplied with their raw materials from the Glasgow entrepôt and their trade directed by the Paisley manufacturers.

In the Lothians and Berwickshire, groups of villages could be distinguished, such as the old salt and sea-coal villages of the Forth and the small rural centres of the Lammermuir foothills. Moreover, a favourable soil and climate enabled the high agricultural labour requirements to compete successfully against the attraction of outside

industries. Villages erected or reconstructed were thus essentially centres of rural tradesmen and handcraft workers serving a capitalised farming population, housed in hamlets on what Cobbett termed the ' steam-engine ' farms.

In east-central Scotland, groups of village burghs had grown up closely integrated with their local environment, such as the old woollen centres in the dens of Fife, utilising wool from the plateau sheep pastures with local water and power from river falls, and the market burghs located between the Old Red straths and howes, and the Highland cattle pastures. Such ancient burghal centres and the home-craft features of their linen and woollen industries did not require the erection of many new villages in Fife, Angus and Kincardine. The new villages were mostly on estates to foster local trade while a few sprang up around isolated cotton mills.

North of Kincardine and in Perthshire, where enclosure had been later and more drastic, numerous ' clearance ' villages were erected to house the superfluous agricultural population. Perthshire, ' particularly adapted for the settlement of villages ' with ' its waterfalls, immediate wool supplies and cottar population had several villages erected ', dependent on cotton and woollen manufacturers. The cottar population of Aberdeenshire, the greatest in Scotland, was an asset to the eighteenth century hosiery industry, but became a social problem with the loss of this industry to the Borders in the early nineteenth century. The villages built to settle the cottars created a pattern of settlements distinctive of the north-east.

In the Highlands, the lack of village life was considered one of the hindrances to its economic development. The Commission for the Forfeited Estates after 1745, the British Fishery Society, and many public-spirited landowners therefore attempted to encourage trade by the foundation of villages and the development of communications. Such erections, however, were spasmodic and often unrelated to local conditions. Several villages were successfully established, such as Tobermory in 1788 by the British Fishery Society and Grantown in 1765 by Grant, but some of the bolder town plans drawn up by city dwellers failed to materialise. Such were Kyleakin, planned in 1811 to be a sea-port, the Southampton of Skye, and Plockton, to be a new Edinburgh of Loch Carron.

In view of the broad regional features of these planned villages, a fourfold classification may be suggested, each of which can be further subdivided :—

(1) Villages associated with agricultural and estate interests.
(2) Manufacturing villages.
(3) Fishing and other villages engaged in coastal trade.
(4) Inland spas, tourist and residential centres.

Scottish Enclosure Acts gave the landowner all the power he required to pursue a policy of enlightened self-interest in the reconstruction of his estate, and there were several types of villages erected, associated with the revolutionary changes of estate management.

There was the settlement established specifically to improve the land around it and house the rural population engaged in drainage schemes, lime burning, quarrying, etc. Villages, such as Racks in Dumfriesshire and Beauly in Inverness, were built on lowland peat mosses or near estuarine flats to improve and cultivate waste land.

Secondly, villages in the Highlands and the north-east were erected to accommodate crofters and cottars cleared from their lands. Archiestown in Elginshire, erected in 1764, is an example of such a ' clearance ' village, which took the place of eleven fermtouns removed in the agricultural improvements and provided the cottars with occupations supplementary to the small lots of land with which they were provided. One public-spirited land owner who had built a ' clearance ' village remarked that ' proprietors who erect villages on a *proper plan* in order to keep their countrymen in the Kingdom deserve better of the public than those who set them adrift without the least of remorse.' Some of the ' clearance ' villages, however, did not long maintain a ' proper plan ', since the village crofters or lotters, with their individualism, tended to disintegrate from the community life planned for them by their landowners. The Earl of Fife's village of Longman in Banffshire was described as having ' more the character and appearance of a colony of small crofters regularly set down than a village '. In Ross and Cromarty and Caithness little attempt was made to set the evicted crofters in nucleated settlements, ' the houses standing at a considerable distance from each other, not in the manner of a regularly formed village '. A planned village was generally most successfully adopted when the employment on the lots or crofts of lands was only supplementary to occupation in local trade or manufacture. Trade introduced into the ' clearance ' villages, however, was often difficult to maintain. Fife Keith in Banffshire was thus described as ' commercially a complete failure ; for except for a few merchants shops and some three or four tradesmen, the villagers may be said to depend on their crofts of land '.

In the Scottish lowlands, ' tradesmen ' villages were more successful, sometimes raising the rent of the estate four or five times its original value. ' There is no other plan,' stated Sir John Sinclair, ' by which a landlord can expect to obtain so high a rent ; hence many intelligent proprietors have erected villages for that special purpose.' Moreover, ' mechanics flocked there since they were exempt from the restrictions of incorporated trades in burghs '. Settlers were attracted by long leases while landlords profited from the high rents of tradesmen and handcraft-workers which farmers could not afford to pay. Springfield in Dumfriesshire is an example of a tradesmen village, set up by Sir Wm. Maxwell in 1791. It was advantageously located on the main Carlisle-Port-Patrick and Glasgow roads, near a coal supply and small harbour. The villagers, chiefly cotton weavers and tradesmen, were given five to six acres of land at a moderate rent.

While some landowners sought to make money by their village lands, others actually laid out capital on villages designed to beautify their estates, usually erected to enhance the entrance drive to their country seats. These ' estate ' villages were frequently the modern reconstruc-

tions of medieval castletouns, exemplified by the 'Newcastleton' built by the Duke of Buccleuch to replace the hamlet of his Border Keep in Roxburghshire. Security and change in social status no longer necessitated that township and castle should be so closely related, so in the new estate plans the old hamlet obviating reconstruction was removed and rebuilt further from the proprietor's house on a model plan. Thus Gavington in Berwickshire was built on a new site and the estate workers were induced to abandon their old properties on very advantageous grants of land. Gifford in East Lothian was reconstructed at the entrance to the Marquis of Tweeddale's residence and the village beauty preserved by the rent of sixty acres of grazing land entrusted to the villagers. Kenmore, at the Marquis of Breadalbane's estate in Perthshire, formed part of the carriageway between the church and the residence, complete with a village archway. The inhabitants were permitted to live rent free on condition that they exercised some trade and kept their houses clean. Fochabers in Morayshire, originally embarrassingly near the residence of Lord Gordon, was removed a mile away, and given a new imposing plan with a handsome square and town hall. Smaller estate villages were due to the reconstruction of kirktouns such as Monymusk in Aberdeenshire.

Distinct from the first group of villages enumerated were the manufacturing villages and isolated factory settlements, often however, analgous to the 'tradesmen' villages since the high rents and industrial speculations were usually the foremost interest of their proprietors. Such villages were erected at a time when the countryside still maintained positive values of its own and rural surroundings were considered more attractive and healthier for the location of urban workers than the city. Philanthropists who showed themselves also to be keen business men, such as Dale and Alexander, upheld the superior value of the country and pointed out the necessity to stem the urban immigration. English town-dwellers were actually settled on the manufacturing village of Gatehouse-on-Fleet in Kirkcudbrightshire, and Irish immigrants in Catrine in Ayrshire. Lord Gardenstone, proud of his achievement at Laurencekirk in Kincardineshire could say. 'I have tried in some measure a variety of the pleasures which mankind pursue, but never relished anything so much as the pleasure arising from the progress of my village.'

The manufacturing villages were generally isolated factory settlements with cotton or woollen mills, bleaching yards or iron foundries. The cotton mill villages formed the most important group, of which Catrine, New Lanark and Deanston were examples. Such villages, primarily dependent on water power, were situated along rivers, the village plan conforming to the topographical features of the river terrace, and the predominant position of the cotton mills upon whcih all life centred. Catrine was described in the Ol dStatistical Account as 'entirely a new creation, and owes its existence to the flourishing state of the cotton manufacture.' Employees of the mill were attracted to the village by the employment and use of houses built for them. With the decline of the cotton industry, those near a coalfield or early entrenched in their industry were able to survive the economic changes. But manufacturing villages erected after the beginning of the nineteenth century sometimes had a disastrous miscarriage in their plans. An example of this is Brydekirk in Dumfriesshire which, instead of being a manufacturing centre as it was planned to be, remains to-day a small hamlet.

The third group of settlements which have usually maintained distinctive features, the fishing villages, have done so because of their aloofness from land interests. Among the numerous fishing villages, particularly of the north-east, two types can be discerned. There were those erected by the British Fishing Society whose object was to develop the herring industry. Tobermory, Ullapool and Louisburgh (Wick), were the most successful results of their efforts. Others were established along the Cromarty coast by groups of migrant fishermen from the larger centres, mostly in the early eighteenth century. Ullapool, chosen for its central position near the west coast fishing grounds, was planned in 1758 to develop the herring industry, but building did not commence until thirty years later. The new plan of the village and its land was drawn boldly over the lochside moorland of Loch Broom, incorporating the older fermtouns and their infield lands. Several hundred acres of land were parcelled out into lots, with pasture, peat fuel, building stone and limestone nearby, and every encouragement given 'to promote the establishment of some useful manufacture for the advancement of the infant village'. Road communications hindered the latter and Ullapool has remained a fishing village with a seasonal tourist trade.

The second type of planned fishing village was that erected privately by landowners, in association with their land clearance schemes. Helmsdale is an example of a village created as a fishing port for the herring industry, where cottars removed from their lands in the Sutherland estates were housed. It was laid out by the Earl of Stafford in a regular plan upon the flats of an estuary. Deep water inshore, sheltered position and suitable location for the cottars were the chief factors for its choice. Cullen in Banffshire is another type where an existing fishing village was added to by a crofter community displaced from the land. Sea-town, with an untidy plan, shows only one regular feature, the gable ends of the houses placed in the direction of the prevailing north-easterly gales. New Town, to landward, is built on a regular plan.

In addition to the fishing villages, several small harbour settlements were established in association with industrial activities, such as the group of slate villages of Argyllshire, of which Easdale is an example, built between the quarries and the harbour. Other examples are Brora in Sutherland primarily built for the shipment of coal to Helmsdale and other clearance villages, Kingston erected by a private company for the export of Speyside timber, and Ardrishaig engaged in the shipping activities of the Crinan Canal and herring fishing. Several small ports were also built along the Galloway estuaries.

The fourth type of villages erected was the inland spas and other tourist resorts. Such spas centred around mineral springs with their own distinctive social features were exemplified by Sir

W. Scott's novel 'St. Ronan's Well'. It well illustrates the period at the end of the eighteenth century when the country, led by gentry, still possessed a leadership in society and fashions based on landed capital. Villages, such as Bridge of Earn and Moffat, were built as select residential resorts, where an older village nucleus was extended by the development of large villas on a southward facing the slope of the valley, and near the mineral springs. Bridge of Earn consists of a bridge-head village built in 1769 and the new developments planned in 1832. The social life and attractive scenery were considered more important than the medicinal values of the mineral waters, so that a doctor ascribed his patients' recovery ' to the less equivocal agencies of change of air, healthful exercise and buoyancy of spirits, the usual concomitants of rustification . . . where the patient is placed in the situation of all others most conducive to speedy recovery'.

Some inland spas, such as Ballater became more noted as tourist centres. Tourism in the Highlands, however, was not popularised until later in the nineteenth century, by the initiation of the movement led by Queen Victoria, which may be termed Balmoralism. This led to the further development of villages already created, such as the military and trading settlements of Fort William and Callendar, and the tradesmen villages of Pitlochry and Grantown-on-Spey. Another movement was the establishment of west coast residential centres, conveniently near Glasgow's growing population. At Dunoon, Oban and Lochgilphead, villages were erected in the early nineteenth century, associated with the introduction of steamship communications with the Clyde and the growing appreciation of Highland scenery.

The planning of villages may be conveniently summarised by the enumeration of some of the physical features of their layout. The villages were usually planned in harmony with the surrounding countryside since they were new features within a new landscape created by the proprietor. A village, such as Kirkowan in Wigtownshire, therefore, sat naturally within the orderly landscape. For the site of a village it was considered of primary importance to secure ' an eligible situation, dry foundation, abundance of spring water, and if possible running water, abundance of fuel, specially coal easily procurable and material for building'. To develop the settlement, ' it should be near a thoroughfare or public road ' but ribbon development was considered highly inconvenient to the villagers. Some roadside villages were therefore built with a width between the two rows of houses, sometimes sufficient for the development of a village green. Eaglesham in Renfrewshire is an example of how such a model settlement could be laid out ; the wide green safeguarded against too much cross-street communication and at the same time provided a rural setting for its cotton mill and a charm for the estate on which it was built.

Square villages were usually planned to develop easily with the expansion of trade. According to a village planner of 1803, such a regular plan 'should be made to suit the shape of the ground . . . and capable of being enlarged at pleasure, so that it has the appearance of a complete village, however small, and of a compact regular town however enlarged'. ' A row or square of houses built along one street and in the middle a Kirk, Tolbooth or Courthouse', provided the axis of crystallisation for the growth of such village burghs. This is examplified by numerous Highland plans such as that for Ballater made in 1808. Adjacent to the houses but not interfering with any likely town growth were the two-acre lands leased with each house. In the ancient burghs, growth was related to the control of the communication network of the marketing area. In the new village burghs, trade was fostered from *within* and expansion was related to this growth, hence the importance of the central square regularly laid out. When the new settlement, provided with burghal features, has remained only a village in size, such as typified by Dufftown in Banffshire, the Tolbooth or Courthouse are scarcely more than architectural ornaments of the plan.

An important feature of the new plans was the division and use of the village lands usually rented on favourable leases. The extent of these lands varied according to the character of the immigrant population, whether urban or rural, and the function of the village. In manufacturing villages the people were not given so much land as would interfere with primary occupation in industry. But in rural centres of rather isolated areas, the villagers were often granted sufficient land to maintain them with at least supplementary occupation. Front gardens were discouraged, attributed to the traditionally untidy appearance of the older roadside settlements, and also due to the grid features of the square village burghs which favoured the equal distribution of land among the settlers away from the village.

The settlements erected in the period 1745–1845, partly maintained the medieval traditions and functions of the Scottish village burghs and, partly assumed the leadership acquired by landed capital of country as opposed to town life. The first became outdated by the establishment of police burghs while the second was subjected to the intensive penetration of urban products and fashions. Many Scottish villages have ceased to be local centres for manufacture or trade and are therefore anachronisms. As Scott-Moncrieff has said ' It is important, that those who believe the village and the village community to be a good thing, should realise the profundity of the problem to-day. A village cannot live on its pleasantness. To exist, it must perform some function in the social and economic life of the community'. History projects itself into the present. In the difficult task of the reconstruction of our rural society, the lessons afforded by village planning in the past may well be considered as a relevant study for present country planning in Scotland.

[*Paper read to the Section of Geography at Dundee on August* 29, 1947. *Based partly on the results of research undertaken for the Planning Division of the Department of Health for Scotland to whom acknowledgement is made by the author.*]

SECTION J.—PSYCHOLOGY

ABSTRACTS OF COMMUNICATIONS

READ TO THE SECTION AT THE ANNUAL MEETING
OF THE ASSOCIATION IN DUNDEE

AUGUST 28, 1947 (MORNING)

Perspectives in modern psychology

By Prof. T. H. Pear

PERSPECTIVES, not only in psychology and other biological sciences, but also in the physical sciences, depend upon the personality, character, social and economic status, even the political views, of individual leaders. This fact weakens an older belief in the inevitable progress of ' Science.'

Distinctions can be made between predominantly extraverted and introverted psychologists, those with differing dominant values, and those who are relatively sensitive or insensitive to the social world in their immediate vicinity. After comparing several perspectives it may be possible to construct one which works fairly well.

During the past twenty years, individual and social psychology seem to have become less sharply distinguished. The difference between the ' nomothetic ' and ' idiographic ' approaches is more striking and may perhaps soon be observable in other biological sciences. The fact that each personality is uniquely structured discomforts those who assert that the function of science is to discover general laws, not to deal with individual cases. Yet in the Forces, the problems of marked differences between individual personalities were often handled successfully, and records of these results will be of use to psychology. Recent tendencies to study relatively small social organisations, e.g. the family, the leaderless group, the social working unit, supplement and often correct vague generalisations (still made by influential non-psychologists) about ' national character.' The culture pattern theory stimulates attempts to describe and to understand the activities of the psychiatrist, the psychiatric social worker and the psycho-analyst.

A note on Humphrey's Paradox

By Mr. D. C. Fraser

In Humphrey's original experiment, subjects were conditioned to raise their hands on the sounding of a musical note, though not responding when the note was included in a melody or arpeggio. Hull has explained this result by his neural interaction theory, as follows. The notes were produced by striking undamped metal cylinders ; hence when the note G occurred in, say, the arpeggio CEGC, the preceding C and E were still vibrating. Thus the combination of the afferent impulses from G with those from C and E might weaken the reaction potential sufficiently to produce external inhibition. Further, C and E would have developed a considerable amount of conditioned inhibition, which would reduce G's reaction potential.

A fresh experiment was devised to overcome Hull's criticisms. Stimuli were produced by Stern Variators, so that each note ceased completely before the next note commenced. A very simple Gestalt, viz. ' Cuckoo ' was chosen, the second note being the conditioned stimulus. Subjects were negatively conditioned to a range of stimuli far above or below the conditioned stimulus, but the first note of the Gestalt was excluded, so that no reactive inhibition should be carried over to the second note. It was still found that no subject raised his hand when the Gestalt was presented, although the strength of the conditioning to the single note had been fully demonstrated by one of Hull's own criteria, viz. resistance to experimental extinction.

The scientific study of national character

By Mr. Geoffrey Gorer

At all periods and in all societies the observation has been made that groups of people belonging to specific societies act in regular and consistent ways and that membership of a given society entails the more or less complete sharing of idiosyncratic ideas and ideals, methods of interpreting the world and typical ways of reacting to different situations which are specific to that society and are not shared completely with any other society. These aspects of shared behaviour

common to a society can be called national character.

Although these observations have probably been made ever since societies came into more than casual contact with one another, they have not, until very recently, been amenable to scientific analysis and investigation. The commonest explanations for these observations were first mythological or supernatural (e.g. ' chosen people ') ; when mythological ideas were abandoned, explanations were derived from ' folk science ', statements which were treated as though they were rational but which are not founded on the observation, cross-checking or experiment which accompanies true science ; the chief explanations of folk science were ' race ', climate, diet, degree of technological development. The evidence from social anthropology however gives the data for refuting such assumptions ; peoples of the same ' race ', climate, diet and degree of technological development have been described showing the greatest contrasts in behaviour and character.

The diffusion of Freud's theory of psychology as developed through the practice of psycho-analysis changed the type of data which anthropologists had previously collected. First, data showing the localized nature of many of the phenomena Freud had treated as universals were collected ; but subsequently anthropologists started paying minute and detailed attention to the child-rearing practices of the tribes they were studying as well as to adult behaviour ; and, the necessary theoretical corrections having been made, it was found that there was a correspondence between the social patterns of child-rearing and the typical or preferred adult character in the society, analogous to the correspondence posited by Freud and his followers for the vicissitudes of individual infancy and childhood and the resulting adult character. A number of the crucial variables have been isolated, though their interconnection is not yet determined.

By 1939 some twelve primitive societies had been analysed from this point of view and the national character (or characters, varying with sex and status) described. The outbreak of war put a stop to further field-work ; but the exigencies of war raised strictly analagous problems for understanding and predicting the behaviour of our enemies and, to a lesser extent, of our occupied allies. Despite very considerable technical and scientific difficulties and some advantages derived from the fact that the societies now being studied were literate, pragmatically adequate approximations were obtained.

It was suggested by the author that the systematic study of national character is a potentially useful discipline for implementing and bringing nearer to reality the older-established disciplines of history, economics, political science, sociology and psychology ; and that it is indispensible for the adequate study of national or international politics.

Personality traits and political ideology : a field study on German prisoners

By Prof. H. V. Dicks

The author gave a condensed account of a war-time investigation of a sample of German prisoners of war by intensive psychiatric interviews. The hypothesis tested by this work was similar to that given in Mr. Gorer's paper, although no contact existed at the time of the field work (1942–44). It was presented as a contribution to methodology rather than as a piece of ' finished ' research.

Pilot studies and previous knowledge of ' German character ' suggested that a number of traits of behaviour might be found associated with a fanatical or ' tough ' Nazi ideology, and vice versa. The traits were defined according to psycho-analytic concepts.

One hundred and thirty-eight men, selected at random from among inmates of a transit camp for recently captured Germans, were examined according to a schedule designed to elicit salient data in the personal history and certain listed traits which were scored on a 3-point scale on clinical judgment. Both background data and concentration of traits were compared by the X^2 method with the degree of Nazi ideology of the subjects, as rated on a 5-point scale by consensus of other interrogators and the investigator.

Significant clusters of traits were found, in the case of Germans at the Nazi end of the scale, which were less marked in the personalities of men at the non-Nazi end of the scale.

August 28, 1947 (Afternoon)

Rehabilitation of an industrial depressed area

Mr. C. A. Oakley gave an account of the ways in which new work was brought into the depressed areas to provide them with fresh employment.

Three approaches were mentioned for getting a better balanced distribution of industry throughout the country : (*a*) by halting the decay of some of the older industries in the development areas ; (*b*) by encouraging the formation of new companies in these areas, in the hope that some will eventually give employment to many people ; and (*c*) by persuading firms from other parts of the country to establish factories, usually branch factories, in these areas.

(*a*) Although the phenomenon of boom and slump has been examined by economists, many psychologists feel that a principal contributory factor is to be found in the human weakness for being too optimistic when things are going well, and for being too pessimistic when they are going less well.

The old theory of there being three generations from clogs to clogs, with its implications, is no longer applicable because the family element in the administering of these undertakings plays a less dominant part than formerly. It seems abundantly clear that progressive industrial companies rely very largely on the reinvigoration they receive from their bright young men, and the less progressive companies do not care very much even if their young men do not stay in their employment at all. One of the first indications that an industrial district is on the decline is when those of its young men who are keen to get on decide that opportunities for them are lacking and go elsewhere.

(*b*) The industrial estate scheme was originally evolved in the depressed areas just before the war, to enable young companies to be established, in the hope that perhaps 5 or 10 per cent. would eventually become concerns of considerable size. That this hope had been justified was shown by there being 7 firms, out of the 90 located on the Hillington industrial estate in the year before the war, who were making very considerable progress —for instance, a rise from 35 employees to 465, and the others 46–250, 50–250, 250–435, 25–173 and 30–120.

(*c*) The realisation that these projects had to be regarded as investments for the future rather than as material contributions towards reducing unemployment immediately, led to the Distribution of Industry Act which in particular sought to persuade large undertakings in the prosperous areas to establish branch factories in the centres of unemployment. A start had been given during the war, when quite a number of companies established branch factories in the development areas and had since kept them on. In Scotland 32 of these branch factories had been constructed and 24 of them were still in use. Most of their managerial staffs were comparatively young and keen to get on. To them the former depressed areas were their centres of opportunity. Many, too, had a fresh outlook on such subjects as environmental conditions, personnel management, canteens, joint production committees, movement study, technical research and marketing. Already they were having a considerable influence on the general atmosphere of the towns in which they had come to live.

Since the end of the war the provision of Government financed factories available for letting had greatly increased this movement from the South and the Midlands, and already almost 100 companies who previously had no manufacturing interest in Scotland had started branch factories in Scotland. Including the war-time factories there were now (or would shortly be) no fewer than 124 of these branch factories in Scotland, and the number ultimately would probably pass 150. Never at any time had there been such a diversity of new processes and products being established in Scotland, and in effect another industrial revolution was taking place in Scotland. The total number of workers who would be involved would eventually be between 100,000 and 200,000.

Dr. H. S. Phillips discussed the problem with particular reference to Dundee, which in common with the whole Scottish Development Area, had more people at work than ever before. Unemployment in the Scottish Development Area was 60,000 compared with pre-war figures ranging from 160,000, at the best, to 300,000. Dundee, by contrast, had 2,000 persons unemployed compared with a pre-war total of between 9,000 (at the best) and 25,000. Dundee had been more successful than most parts of the Development Area and only required a limited amount more of male-employing industry to be considered as enjoying full employment. At least five million pounds per annum more than in the best pre-war years, was going into the pockets of Dundonians, even after the increased cost of living had been taken into account.

Since VE Day, 43 building projects had been approved in Dundee, 17 of them involving entirely new factories. Half of these projects were Treasury financed. They were already giving work to nearly 2,000 people and would ultimately provide work for at least 8,000. Manufacturers had come from Luton, Preston, Liverpool, London, Essex and the United States. Local manufacturers were either expanding or modernising.

Some reasons for success in this area were :

Dundee, unlike other depressed areas, had previously had a strong tradition of women's work. There was an extra woman (20–44) for every four men between 20 and 44. Thirty-three per cent. of Dundee's married women, as compared with 7 per cent. in Glasgow and Edinburgh, worked during the depression, keeping the family together through appalling sufferings. (This work was nevertheless intermittent and short-time—during a period when 42 per cent. of Dundee's jute employees were registered as unemployed.)

Dundee has an attractive location on the banks of the Tay.

The city had not suffered from heavy migration (compared with 12 per cent. for Merthyr Tydfil).

There was a strong sense of civic pride.

The pre-war trek south to new factories had changed into the beginnings of a trek north, encouraged and made possible by the Distribution of Industry Act. The blitz—and now labour shortages—had taught industrialists the short-sightedness of over-concentration in the south—breaking the vicious circle of snowballing development in Greater London.

Books on Scotland were telling southerners the true facts about a country more populous than Norway or Denmark.

The major problems of rehabilitation were :

The finding of good sites, which had been successfully solved in Dundee by the creation of a fresh industrial belt to the north of the city. 400,000 sq. ft. of space had already been let on the Estate.

The employment of relatively unfit workers. Special efforts were being made in Dundee to cater for these, by firms and Ministry of Labour.

The danger of closure of Scottish Branch Factories. This was no greater than the danger in English Branch Factories. There were now enough factories in Dundee to take up slack in the event of depression.

Training of adults to suit them for new industries and give demoralised workers new confidence. This was receiving attention.

Shortage of younger workers due to raising of school leaving age. New methods of pre-vocational training were coming in and more attention was being paid to welfare.

Need for more houses. Dundee had an excellent record of 1,200 houses built since VE Day, 50 of these being for ' key ' workers.

In conclusion the author said that, if Dundee obtained a few more male-employing factories her problem would be full employment, not unemployment. Problems connected with full employment were :

If Dundee's women were to remain at work there would need to be more nurseries and canteens.

Continued research into improved technical and social methods of increasing production was required.

Greater provision of cultural outlets for people would be required.

Spelling defects in cases of brain lesion

By Miss A. E. Sladden

The author discussed the problem of spelling defects in brain-injured patients, and presented four cases of dysphasia where defects of auditory or visual perception played a part in the spelling performance.

The introduction dealt with the nature and localisation of acquired spelling defects. Reference was also made to spelling errors in children and in normal educated adults. Four main classes of acquired spelling defect were outlined : disturbances in verbal formulation, in auditory or visual verbal discrimination, and disorders of visual-spatial perception and construction.

Two cases were presented where the spelling defect was related to defective auditory analysis. The errors here were contrasted with those of a patient with dyslexia, dysgraphia, and blindness due to bilateral occipital lesions, where the spelling disturbance resulted from defective visual verbal memory and a compensatory dependence on a phonetic approach.

The last case was more complex, and showed several interesting features. Two specific types of error (substitutions at the beginning of a word, and reversals) were superimposed upon a generalised dysgraphia, the writing disturbance being related to a visual-spatial disorder and constructional apraxia, where disturbances of conjugate eye-movements and a neglect of the left half of visual space play an important part.

The errors of these patients were analysed and compared with those made by children and normal adults. Some conclusions were drawn regarding the factors involved in the normal spelling process and its disorders.

August 29, 1947 (Morning)

Selection for management

Mr. Alec Rodger said that British industry would need an annual intake of about 12,000 potential managers. Most of them would be for small firms, which would have to make their own selection arrangements. These firms should be encouraged to pay as much attention to their recruitment procedures as to their selection methods. They should fortify themselves with accurate, full and well-balanced information about the nature of the duties their selected candidates will have to perform. They should be particularly knowledgeable about the danger-points in the occupation. They should think far more about the activities and situations involved in it than about the qualities they imagine to be required by it. They should not expect more than a little assistance from psychological tests. They should, whenever they could, make use of the modern technique of getting candidates to do things, or talk about things, together. Above all, they should take their interviewing seriously, always bearing in mind the fact that the important questions are not the ones they are going to ask their

candidates, but the ones they are going to ask themselves about their candidates when it is all over and the final assessments are being prepared. As many as possible of their *ad hoc* selection teams should include a psychologist, who should nevertheless keep his place as an adviser.

Dr. N. A. B. Wilson said that good selection for management, as for other jobs, depended upon : (i) a recruitment policy which is good and known to be good, (ii) good selectors, and (iii) a good selection procedure, founded upon a rationale both theoretically sound and acceptable to the people affected. (iii) was useless by itself unless (i) and (ii) were right, but the relevance of (i) was not usually grasped, nor were appropriate criteria for (ii) very often forthcoming. It was important in practice that the job-study pre-requisite to (iii) should be done, at least in part, by study of the people actually doing the job. Further, such studies required the use of a systematic scheme of examination and report of the kind described in various articles by Alec Rodger and the N.I.I.P., P. E. Vernon, M. D. Vernon and others.

The degree of elaborateness appropriate in a selection machinery would depend upon the importance of the jobs to be filled. For the most important it might be remunerative to obtain all six kinds of evidence used by such new-type boards as the Civil Service Selection Board, namely :

(*a*) curricula vitae, together with referees' reports on candidates from school days onwards,

(*b*) interviews,

(*c*) performance in an extensive series of ' practical exercises ' (analogous tests), both group and individual,

(*d*) results of a scholastic examination,

(*e*) results of a battery of cognitive tests, and

(*f*) ' results ' of ' projection tests.'

In practice the major emphasis was upon (*a*), (*b*) and (*c*). The most important use of (*d*), (*e*) and (*f*) was in interpretation and evaluation of the other evidence.

Finally, the amount and political importance of selection done by promotion boards should be noted. Their function was not to investigate *de novo* but to use the evidence of cumulative records of candidates' performance. Because of its effect upon morale internal selection must, at all costs, seem fair and understandable to employees. Otherwise, there would be retrogression to promotion entirely by seniority or formal (especially academic) qualification.

Dr. T. Ferguson Rodger also spoke during this session.

August 29, 1947 (Afternoon)

Standards of acceptance in vocational selection

By Mr. D. Straker

Published accounts of the activities of industrial psychologists during the second world war have been too much concerned with the preparation, validation and use of intelligence, attainment and aptitude tests for the allocation of personnel to specific duties. The tendency to give undue prominence to the results of such tests has been due to the necessity for allocating vast numbers of personnel in the minimum time by scantily trained interviewers. An unfortunate consequence is that many of the lessons which have been learned have only indirect application to civilian problems.

The peace-time recruitment problems of the Regular Service element of the Royal Navy were, however, closely akin to those of a large industrial organisation. In addition to psychological test data the selection officer must take into account for each candidate such factors as general background and circumstances, work history, physical make-up, interests and disposition. And he should not forget that in a work situation, as in any other situation, an individual behaves as something more than a number of definable attributes.

The weight which could justifiably be given to test data in the general picture of a candidate for employment must depend chiefly on the quality of the selection officers, the time available for selection, the state of supply and demand for labour, the state of motivation among the candidates, the range and nature of likely jobs and specialisations, and the standard required to be acquired on completion of training. Where time allowed and where skilled interviewers were available in adequate numbers, the use of rigid rejection levels on psychological or educational tests should be resisted. When allocation has to be carried out by less skilled interviewers it may be expedient to adopt rigid or semi-rigid test minima. But however rigid the system provision should be made for special consideration to be given to applicants who possess unusual attributes and qualifications.

Changes in mental ability with age

By Mr. J. C. Raven

The paper described an attempt to trace the development and decline of intellectual activity and acquired information, from infancy to old age.

Two tests were described, a non-verbal test designed to assess a person's output of intellectual activity at the time of the test, irrespective of his acquired information, and a test of his general fund of acquired

verbal information, involving the least possible intellectual activity at the time of the test.

The results of giving these tests to 2,200 children of from 4 to 14 years of age, to 3,600 militiamen from 20 to 25 years of age, and to 3,000 civilian men from 18 to 65 years of age were summarised.

The normal development, dispersion, and decline of the capacity to understand a fresh method of thinking, and recall of previously acquired information, were discussed. Gaps in existing information were noted, and the bearings of some of the findings upon education, industry, and mental health were indicated.

Changes in abilities from 14 *to* 20 *years*

By Dr. P. E. Vernon

Little information has been available hitherto on changes in abilities between 14 and 20 years because of the difficulties of securing comparable samples. Recently, however, tests standardised on representative populations of Royal Navy or Army recruits have been given to larger groups of children, and to 17–19 year adults, with the following results :

(1) General intelligence or '*g*' shows a very slight increase from 14 to 17 in boys leaving school, a greater increase in those who receive further schooling.

(2) A decrease starts after 17 among men in lower-grade occupations, but the level is maintained to a later age among men in more 'intellectual' occupations.

(3) Unless there is further education, educational attainments decline rapidly from 14. For example the bottom 10 per cent. of the adult population at 18 years have maximum spelling and arithmetic ages of about 8 to 9 year level instead of the expected 11 year level.

(4) Even without any technical education there is a marked increase in ability at mechanical and spatial tests and some performance tests like Kohs Blocks, i.e. in '*k*' factor.

These results have important bearings on the establishment of test norms, and point to a new conception of abilities as dependent largely on the extent to which they are *used*.

September 1, 1947

The Psychology Section joined with the Education Section in a discussion on *The allocation of children for education*, which was reported in *Education*, Sept 12, 1947.

September 2, 1947 (Morning)

The first part of the morning session was occupied with a discussion on *Methods of public opinion surveys*, in which the main papers were read by Mr. H. Durant and Dr. H. J. Eysenck.

Do the public tell the truth ?

Mr. Durant said that, in considering how far the public told the truth in opinion surveys, the general rule was that they told the truth unless there were good reasons to the contrary. Assuming the satisfactory framing of questions, these reasons were :

(*a*) Social prestige (e.g. it is difficult to get accurate answers concerning church-going) ;

(*b*) Social sanctions (e.g. admitting failure to vote at a General Election) ;

(*c*) Taboos (as on matters concerning sex).

These obstacles could be overcome, but a number of different techniques had to be adopted, since there was no simple, general solution.

For example, accurate answers about church-going could be obtained if the contact was questioned about the most impressive sermon they recalled hearing recently. Those who could not recall one explained their failure by not having been to church for some time. People were persuaded to admit failure to vote at a General Election by adding to the question on how they voted the phrase : '... or were you prevented ? '

Criticism of quantitative analysis was often based on the charge that it did not probe people's motives or reasons for their opinions. One fundamental fact was overlooked by these critics. In the vast majority of cases people were not aware of their motivation, nor of their reason for holding views. Only very skilled, detailed, persistent interviewing could elicit this kind of information and this type of interviewing could be applied only to a sample of minute proportion. Quantitative analysis supplied explanations in terms of correlations. They might be between opinions and events, they might be between views and circumstances : but such correlations were seldom, if ever, present in the mind of the respondent, as can be seen by considering how many people say : 'I hold this view because I am over fifty.'

In a paper on *Equal-appearing interval scales or single-question surveys : an experimental comparison*, Mr. Eysenck said that a comparison was made between the responses of a sample of 165 subjects to (*a*) an equal-appearing interval scale for the measurement of anti-semitism, and (*b*) two questions regarding attitudes to the Jews taken from recent polls.

The reliability of the scale was established on 400 students ; comparisons of different methods of scoring (Thurstone's, Likert's and the author's ' scale-product ' method) showed that the scale-product method gave a reliability significantly higher than either of the other methods.

Reliability of the ' single questions ' was established by correlating them with the scale ; similarly their validity was established by comparing responses to the questions with scores on the scale. Correlations were high : 0·93 and 0·80 respectively. Criticism of single-question polls on the basis of their lack of reliability and validity was therefore considered disproved.

Single-question polls were criticized, however, because of the difficulty, demonstrated experimentally, of interpreting results in the absence of knowledge of the scale position of the items used. It was also shown that scale position is not the only factor which influences per cent. endorsement of any particular item ; the degree of ' stereotypy ' exhibited by each item causes great differences in per cent. endorsement even for items of similar or identical scale position.

It was concluded that unless steps were taken to overcome these difficulties, results obtained from single-question polls could not be said to be acceptable scientifically. Methods were outlined for solving this problem.

The discussion on *Public opinion surveys* was followed by two papers :

Attitudes of school children to interest in team games and to compulsory team games

By Mr. J. R. Clark

Scales for measuring interest in team games and to compulsory games were compiled and standardised, and applied to eighteen different groups of approximately fifty children of varying age (11 to 14 +), sex and social status. The following conclusions were drawn :

(1) Interest in team games increased from 11 to 14 + over the whole school population, and more especially in the non-fee-paying schools.

(2) Interest was greater at 11 + in schools where there was a ' games tradition,' also in schools of higher social status.

(3) Boys showed greater interest than girls at 11 +, but there was no significant sex difference at 14 +.

(4) Disapproval of compulsory games increased with age, particularly in the boys' fee-paying schools.

(5) There was a distinct possibility that social status influenced the attitude to compulsion at 11 +, though the ' games tradition ' tended to blur the distinction. There was no direct influence of social status discernible at 14 +.

(6) There was a significant difference of attitude to compulsion between boys attending Junior and Senior Secondary Schools, the latter showing greater disapproval.

(7) Boys tended to disapprove of compulsion more than girls, and this difference was noticeable at 14 +.

Subsidiary investigations indicated that those who show most interest in team games may be most in favour of compulsion, also that the more intelligent children may disapprove more strongly of compulsion.

The educational and social background of the English judges

By Miss N. E. Robertson and Mr. J. A. Waites

The paper referred to a section of a larger investigation into the educational and social backgrounds of our rulers. Questionnaires concerning school, university and adult education, parental background, participation in local government and business interests were sent to the members of the Cabinet, Members of Parliament, heads of Civil Service Departments, judges, recorders, stipendiary magistrates and officials of the House of Commons.

The unwritten Constitution of England had evolved from the decisions of judges upon a long series of individual cases, and this same process was continuing. In certain conditions, modern judges still had power to overrule the Executive. This part of the stability of our civilisation depended on about a hundred individuals holding the office of Judge.

Their decisions, often internationally significant, were presumably based upon psychological principles similar to those which actuated mankind in general. Modern research in social psychology had indicated that personal decisions were greatly influenced by the ' pattern of culture ' in which the individual had been reared and that in which he was now situated.

Though the investigators had been unable to arrive at a clear-cut total perspective of the patterns of culture from which our English judges come, it had been possible in the present investigation to discover and record some of the chief features of their educational and social background. The paper attempted to indicate the paths followed by the majority of our judges in school and university education and the social strata from which they had come to their position in the Judicature.

SEPTEMBER 2, 1947 (AFTERNOON)

The section took part with the Economics Section in a discussion on *Incentives in industry*, which is reported elsewhere in these pages.

The following papers were read in the Section's meeting room :

The part of the psychologist in the moral development of the society

By Dr. M. Sturt

It has been argued on the one hand that the duty of the psychologist is merely to investigate and record, and on the other that he should take sides in the controversies of the day and use to the full his powers of persuasion. His true rôle in society is deeper and more important than either. The collection of facts is always important, but belongs in essence to an early stage in the development of a science, before a knowledge of the factors make control possible. In much of psychology the stage of control has been reached.

The teaching of morality in the past was an individual affair of the cane and the moral story. To-day the psychologist, in alliance with others, has evolved concepts and methods that have a direct moral bearing. With the educationalist he has evolved theories of stage and rate of development and produced the willing and happy school child : with the doctor and criminologist he has evolved theories of repression and substitute satisfaction and he has done much to alleviate the vice that springs from mental maladjustment. He is now entering the field of sociology. The ideas of frustration and consequent aggression are comparatively new. Newer still is the realisation that the whole structure of society, economic, social and political, affects the moral type of citizen, and that social pattern can be imposed from the nursery. It is the part of the psychologist to show how society should be remoulded in the light of this new knowledge.

Experiments with pictures

By Mr. R. W. Pickford

In a previous experiment, factorial analysis of eight aesthetic qualities in a group of 18 pictures rated for these qualities by 59 judges, revealed a general or ' aesthetic ' factor and a bipolar or ' technical ' factor. A further experiment was carried out to test these results on a larger number of pictures which were originals, all about 3×4 feet in size and not small reproductions. Forty-five pictures carefully selected to include in varying degrees and combinations ten aesthetic qualities, were chosen in the 85th Exhibition of the Royal Glasgow Institute of the Fine Arts, 1946. They were rated on these qualities by 18 judges who were interested in the psychology of art, and intercorrelations between qualities were factorized.

The first factor was heavily saturated with harmony of design, harmony of colouring and atmospheric effect, and less heavily with emotional expression, interest of subject matter and rhythm or movement. Qualities with almost no saturation in the first factor were photographic accuracy and sentimentality, which had heavy positive saturations in the second or bipolar factor, and impressionistic effect and symbolical expression, which had heavy negative saturations in the second factor.

This experiment confirmed the conclusion of the earlier one. In general terms it could be said that design, feeling and rhythm were the essence of art, but they could be conveyed in at least four ways : photographically and/or sentimentally, symbolically and/or impressionistically.

Psychometric telepathy across the Atlantic

By Dr. J. H. Hettinger

Two series of telepathic experiments were carried out between New York and London in the first half of 1945 and July, 1946, respectively. The transmitting person in New York was perusing an American illustrated magazine while two London percipients, generally referred to in Psychical Research by the misnomer of ' psychometrists,' were giving the impressions they received (in ' psychometry,' the percipient handles, or mentally concentrates on, some object belonging to a person to be contacted).

Although difficulties were encountered with the statistical assessment of the impressions, the results obtained were found not to differ from those successfully secured at shorter distances by the same method, conceived and tested during a piece of research carried out at King's College, London University, before the war. The difficulties met in the assessment of qualitative material were well known to psychologists.

A representative selection of successful results were projected on the screen, showing both concrete ' hits,' such as ' a pony,' and abstruse ones, such as a German general's ' decision of soon going back ' (May, 1945). It was submitted that these pictures contemplated in New York compared with the percipients' impressions received in London at the corresponding time constituted *prima facie* evidence of psychometric telepathy across the Atlantic.

THE IDEAL GEOLOGICAL MAP

By Prof. D. L. LINTON

The sense in which the phrase 'ideal geological map' is used in this article can best be made clear by emphasising a duality of function, and a potential division of labour, that enters into the making of every geological map. On the one hand it is the function of the field geologist to make a faithful record of the rocks and structures found in nature; on the other, it is the function of the cartographer to find the best possible means of representing this record on a map. No doubt field geologists had often in the past to be their own cartographers, but this merging of function, should not be allowed to obscure the fact that the problems of geological mapping as a field technique and those of geological cartography are quite distinct.

To the field geologist the ideal geological map is one in which the portrayal of nature shall be as faithful as a mirror image. Nothing may be shown which has not its precise counterpart in nature, and nothing that can be observed in nature may be omitted. Such a map is not merely ideal, but of course an unrealisable ideal, a counsel of perfection. Rarely, if ever, is nature so prodigal in her manifestations that the field geologist is left without the least room for doubt. Geological mapping is always a matter of interpretation. The geological cartographer, on the other hand, accepts the findings of his field colleague as the best interpretation of nature that is to be had, and seeks to give these findings the clearest possible cartographic expression. This in itself is no small task. Since the first pioneer efforts were made to represent geological facts on maps about 200 years ago, there have been great changes in the idea of what should be mapped, and in the technical means available to the map-maker. Most of the many possibilities have been experimented with and exploited somewhere, at one time or another, and in consequence there is now a great deal of experience embodied in the maps produced by individuals, societies and national survey institutions, which is ripe for review. The beginnings of such a review are attempted here.

There is, I suggest, no real divergence of view as to what the requirements of an 'ideal geological map' shall be. They may be succinctly summarised by stating that such a map must

(*a*) show all the essential or significant known geological detail of the mapped area,

(*b*) by a combination of symbols which is clearly and easily legible and readily understood, either self-evidently or by reference to an adequate key carried on the sheet itself,

(*c*) on a topographical base which is up-to-date, sufficiently detailed for the accurate location of outcrops, etc., closely contoured and does not interfere with the legibility of the geological detail.

The significance of this summary may perhaps be most readily revealed by noting the limitations of the earlier official geological maps. These had, perforce, to accept as a base whatever topographical map was available—in most cases an engraved hachured map against which almost any scheme of geological colouring became muddy and obscure, and whose scale was fixed, by such irrelevant considerations as the limitations of survey technique or the military requirements of the day. Such were the one inch maps of England, the 1/80,000 sheets of France, or the 1/75,000 of Austria-Hungary, and for parts of these and other countries such are still the only maps available. It is perhaps fortunate that the unsuitability of the topographic base was partly compensated by the relatively limited geological information to be shown and the simplicity of the means available for showing it. The information was essentially the product of reconnaissance survey and was restricted to the delimitation of the principal rock types and formations—granite, diabase, schist, chalk, gault, lias, oolite, etc. These were represented simply by engraved outlines supplemented by washes of water colour applied by hand.

It is clear that such maps do not begin to meet the requirements of modern geological science. But it is not equally clear just how those requirements are to be met. Some conclusions, which it is hoped will receive a measure of agreement, can however be drawn from the experience embodied in the multitude

of existing geological maps by a comparative examination, considering in turn each of the main heads (*a*), (*b*) and (*c*), of our summary definition.

The Information to be Mapped

Geological mapping of the stratified rocks has a two-fold basis—age and lithology. Broadly speaking, we may say that all through the nineteenth century geological mapping yielded more and more detail on the latter aspect until all the principal beds of distinctive character in the stratigraphical succession of such areas as the Paris Basin or much of England and Wales had received recognition and, locally at any rate, had been mapped. Overlapping with this development, and continuing down to our own day, the application of palaeontological zoning to geological mapping has led to the ever increasing subdivision of formations and hence to a narrowing of the outcrops which require separate representation. The end of this process is doubtless not yet, but already we have long since passed the point where the available information could be shown on the standard topographic maps of the countries concerned—1/63,360 in this country, 1/80,000 in France or 1/100,000 in Germany.

But increasingly detailed sub-division of the stratigraphical column is not the only source of increased pressure upon available cartographic space. The petrologist, the quarternary specialist, and the structural and economic experts now also make heavy demands on the cartographer. The development of petrographic ideas leads naturally to a more refined differentiation of igneous rocks, a sub-division of outcrops, the recognition of altered, mixed and hybridized types. The improvement in our understanding of the nature and genesis of drift deposits has led to an enormous increase in the factual information requiring expression, and the adequate representation of structural features—exposed and concealed faults, fold axes, cleavage, foliation and the like—and such economic data as the location and character of mineral veins, bedded and other ores, coal seams, pits, mines and quarries, working or abandoned, the limits of ore fields and the extent of mining concessions, still further increases the burden. Even this is not all, for it is to the geological map that we should turn for information regarding the location of wells, springs and boreholes and the location in depth, shown by hydrohypses or otherwise, of the principal aquifers.

All this information has in fact been shown on official geological maps, and in some cases virtually all of it in combination on a single sheet. It is, moreover, my own view that all this information is legitimately to be expected on the geological maps of to-day and to-morrow. One class of facts, however, which certain geological surveys have attempted to show on their sheets (and not without success) should, I think, be excluded. I refer to the data given, for example, by certain German surveys on the character, texture and thickness of the soil and subsoil.[1] Such information constitutes, at best, only a partial and far from adequate statement of our knowledge of the soil where the latter has been examined by pedologists. It has been abundantly proved in many parts of the world that soils must be examined and mapped in their own right by workers who have specialised in their study. Even, however, if soil mapping be excluded from our field, more than enough remains to lead inescapably to the conclusion that scales of the order of 1/63,360 are much too small to allow modern requirements to be met. This consideration has already made itself felt in many ways. The results of private research involving detailed zonal mapping, tectonic investigations or glacial phenomena are almost invariably published at scales larger than 1/30,000 and a cursory examination of the principal journals will reveal examples at scales going up to 1/15,000 or even 1/8,000. Geological maps have for long been printed and published by H.M. Geological Survey for the British coalfields at 6 inches to a mile (1/10,560). On the continent a number of geological surveys have 1/25,000 as their standard scale, while in the United States, the limitations of the 1/62,500 scale have been less severely felt only because each geological folio normally deals with the different aspects of each district ('areal geology', 'surficial geology', 'economic geology', structure and hydrology) on as many different maps.

On the other hand, if scales of the order of 1/63,360 are too small to give adequate expression to the fruits of modern geological mapping, 1/10,560 is for most areas too large. Only areas of considerable complexity or high economic importance could justifiably be represented on published maps at such a scale, and some of the recently published colour-printed six-inch sheets of the London district serve admirably to illustrate the point. They show nothing that could not have been displayed with equal clarity at half the scale or less, and go far to reinforce the conclusion I have reached from the examination of a large number of maps and series, that for

[1] They are given on the *Geologische Karte von Preussen und benachbarten deutschen Ländern* at 1/25,000, in the form of 'fractions' scattered over the lowland areas in red at intervals of about a kilometre. Thus, $\frac{H4}{WL16}$ means 4 decimetres of peat resting on 16 decimetres of water bearing loam.

most areas a scale of the order of 1/25,000 is about the optimum for a geological map which meets modern requirements. Smaller scales are inadequate, and larger scales an extravagance.

One more point remains to be made under this heading—namely to point out that a geological map is a two dimensional representation of structures that in nature have a third dimension. The representation therefore is imperfect unless completed by two things: first, a section displaying the structural relations along at least one line selected as representative; and second, a vertical column showing to scale the relative thicknesses of the strata concerned.

The Colours of Geological Maps

Colour was first applied to geological maps, no doubt, solely with the intention of distinguishing one outcrop from another, and for this simple purpose any colour might be applied to any outcrop, and any two colours might appear in juxtaposition. The French 1/50,000 appears still to be guided by no consideration more systematic than this in the choice of colours for some of its sheets. But in the course of time some systematisation began to appear. Experience must early have shown the merit of what may be called the 'principle of the distinctive horizon'. By that I mean the use of a bold colour for a formation of limited width of outcrop but wide areal distribution which thus takes on the character of an index formation. The run of its outcrop gives an immediate indication of general structure. The gault and cornbrash are well-known English examples, and the principle is still obviously utilised in British maps. Another tendency which early appeared in British maps was that which I will call the 'principle of associative colouring'. For reasons which were in part deliberate and in part no doubt accidental, certain rock types and certain colours became associated.

Jamieson in an address to the Wernerian Society in 1808 had announced the principle that, on a geological map, 'the colours must agree as nearly as possible with nature—that is they must correspond with the most common colour of the rock',[1] and the scheme of colours ultimately adopted by the Geological Survey was evidently based on this conception. The brick red and chocolate colours employed for the New and Old Red Sandstone systems, the grey-black for the Coal Measures, the green for the Cretaceous greensands, and the slaty colours for the older palæozoic rocks are all clearly imitative. By extension of such usage the green originally employed to depict greenstone outcrops is now widely used on British maps for basic intrusives. The bright reds used for acid intrusives may similarly be an extension from the imitation of the colour of certain of our red granites, but the red colours universally employed for volcanic rocks are the result rather of association of ideas. Less obvious is the reason for the typically British use of blue for virtually all the pre-Triassic limestone outcrops, including both metamorphic marbles and the warm-tinted magnesian limestone, and of almost any colour but blue for those coming later in the sequence! Both in their logic and their inconsistencies these early British practices have had considerable influence abroad, and two points in particular may be noted. The imitation of rock colours gave to the colour scheme a harmony which resulted in maps of real beauty—a beauty not likely to be equalled by modern techniques. But it also imparted to many sheets an obscurity and gloom which, coupled with the engraved hachures and wood symbols below, made them almost impossible to read.

From the continent, however, came a contrasted influence. The tendency for certain formations and colours to become associated was developed logically so that colour became an index of age. This principle was, as it were, canonized when such a scheme was adopted by the International Geological Congress at Bologna in September 1881, for the International Map of Europe. On that map each system was represented by a single colour, irrespective of the lithology of its constituent formations; these colours were systematically grouped so that they passed by a species of spectrum order with increasing age from the yellows of the newer Tertiaries, yellow-green for the Eocene, green, blue and violet for the Cretaceous, Jurassic and Triassic, to the dull colours of the Palæozoic systems. Orange and red were reserved for igneous rocks and pink for metamorphics, while within each system older divisions were distinguished from younger by deeper tones. The evident advantages of this systematisation led to its adoption in Richard Lepsius' map of Germany (1/500,000) in 1894–97; in the official map of France (1/1,000,000) in 1905; in the map of Germany (1/800,000) by Johannes Walther in 1920; in the general maps of Rumania (1/500,000) in 1926 and Austria (1/500,000) in 1928–30; and it has been not without influence even outside Europe. But in its original form the sombre colours used for the palæozoic rocks, and the increase in tone in the lower divisions of each system made parts of the map very muddy and obscure. Lepsius therefore lightened some colours in the Bologna scheme and

[1] Quoted by H. B. Woodward in *The History of the Geological Society of London*, 1907, p. 102.

altered others to secure greater transparency, but as all his colours were self-colours, all forms of ornament or overprint being avoided ' on principle ', this process could not be carried far.

On the other side of the Atlantic a logic similar to that which inspired the Bologna scheme was leading to similar results. The second annual report of the United States Geological Survey went to press a couple of months before the Bologna conference and contains a scheme which associated the colours grey, yellow, green, blue, purple and brown with portions of the stratigraphical succession from quaternary to archaean, and reserved red for igneous rocks.[1] Two or three tints of each colour were to be employed and multiplication provided by using a dark and a light tone of each tint and using the former ' as overprints in various mechanic arrangements ' on the latter. The scheme in this form was not proceeded with but in the geological folios that began to appear from 1894 onwards, in the map of North America (1/5,000,000) of 1911, and the general map of the United States (1/2,500,000) of 1932, expression was given to the principle of one colour—one system. The colours range from the yellows and light browns of the Tertiaries, Cretaceous green, blue-green for Jurassic and Triassic, blue, grey, lilac and purple Palæozoics to browns in the pre-Cambrian. In these maps the resources of colour printing have been ingeniously but very simply employed to provide distinctive tints for all the minor formations involved without overprints. This has been achieved by tinting each formation, not with a uniform wash but by single rulings which combine varying proportions of the pure colour with white. Thus on the Apishapa Quadrangle, Colorado, six formations which constitute the local Upper Cretaceous are all represented by rulings of a single tint of green ; the two divisions of the Niobrara Group (Apishapa Shale and Timpas Limestone) are shown by distinctive horizontal rulings ; the three divisions of the Benton Group (Carlile Shale, Greenhorn Limestone and Graneros Shale) by vertical rulings ; and the underlying Dakota Sandstone by ' left-oblique ' lines. For quaternary formations stipples are substituted for rulings ; for igneous rocks cross rulings are employed, often with the triangular interspaces filled solid ; and for metamorphic formations the outcrops are patterned with white flecks. It must be emphasised that with rare exceptions there is no multiple printing of one colour on another after the manner in which mixed tints are produced in British maps, and it is this which keeps these American maps so clean and transparent. The 1932 map of the United States depicts 84 formations, and 83 of these are shown by the use of pure colours.

Ingenious, simple, and effective as is the American method, still greater possibilities reside in the use of overprinted ornaments which has been chiefly developed in Central Europe. This development was in fact foreshadowed in the Bologna map which, for example, overprinted a blue stipple on all systems from the Cretaceous to the Oligocene when these took on a *flysh* facies, and made certain other similar uses of the method. Most later general maps have resorted to it more or less extensively, and in the 1/500,000 map of the Austrian republic (1928–30) its systematic application has led to a map of exceptional detail and clarity for the scale. The most productive examples of its use, however, are found in the large scale sheets (1/25,000) of the surveys of Baden, Württemburg, and Prussia. Here the colours are usually delicate transparent shades, differentiation of formations being effected by overprints of lines, dots, dashes or combinations of these. Thus on the Prussian sheet 2016, Minden (published 1933), only pale orange, yellow, green and grey are used as basic colours, but by the use of overprints in blue, green, grey, orange, brown and red, 56 separate formation colours are developed, of which 26 are quaternary and recent. The Upper Jurassic (weiss Jura) for example, comprises 9 formations on this sheet, represented in pale green with 8 overprinted ornaments : the Middle Jurassic (braun Jura) comprises 7 formations of which 1, 2 and 3 are self-coloured grey and the remainder have blue or red ornaments. What is more the ornaments can be made expressive of the lithology of the minor formations concerned and can also be applied heavily enough on occasion to satisfy the ' principle of the distinctive horizon'. Here, clearly, is a method capable of infinite adaptation and development. It allows us to satisfy at one and the same time the seemingly incompatible principles of one system—one colour, and distinctive colouring for every separately mappable formation.

Overprinted ornaments have, of course, been used on British maps, but their use has been crude, unsystematic and not self-consistent, and above all has been attended by no lightening of the already over-heavy basic colour scheme. We may note that an overprint of red dots has long been used for blown sand, and is almost traditional for volcanic tuffs and ashes. Overprints of

[1] J. W. Powell. *Second Annual Report of the United States Geological Survey, 1880–1881.* Washington, 1882, ' Colours for Geologic Cartography,' pp. xlix–lii and Plates I–VII.

coloured dots have been used for certain conglomerates or sandy formations, even though this has involved omitting the basic colour beneath each dot in order that it should appear! (See, for example, sheet 316, England and Wales, Folkstone Sands.) In other cases the same overprint has different meanings on different sheets, as for example the blue dots on buff which refer to post-glacial sand and gravel on sheets 52 and 53, and to calcareous tufa on sheet 299, and sometimes even different meanings on the same sheet, as in the case of sheet 298 where the same red dots on the same yellow base signify both the Portland *sand* and the Purbeck *marl*. The greatest use of overprints, however, has been on the combined solid and drift sheets of the Scottish one inch map. Here the ornament is applied in black over the full range of colours for the solid formations, to say nothing of the topography. If, as is frequently the case, the colours for the solid formations are strong the drift symbols are lost: if they are subdued as on sheet 16 the topography is smothered by the drift. These maps can only be regarded as partially successful compromises.

Signs and Symbols

The most important of the symbols employed on geological maps, despite the fact that there are some maps without them, are the index letters or numbers to the several formations. In many cases these are rendered necessary by the ambiguity that can arise from similarity of colours on a single sheet, or from divergences in the colour used for a single formation on sheets printed at different times. In all cases they are highly desirable to show the precise position of a bedded formation in the stratigraphical sequence, or of an igneous rock in the adopted classification. In the case of the bedded rocks it is clearly possible to devise, in theory at least, a series of numbers or letters running in numerical or alphabetical order, that shall represent the complete sequence of geological ages and epochs from Cambrian times to the present day, and more than one such system is in use. Oddly enough, however unsystematic British official practice may be in other respects, few systems of formation-indexing are more logical or complete than that used by the Geological Survey. In that system lower-case letters denote the systems from Cambrian *a* to Pleistocene *l*, numerical suffixes denote their principal divisions, and further suffixial ticks the internal subdivisions of each of these; e.g. h = Cretaceous, h^5 the Chalk, and $h^{5'}$ the Lower Chalk. Unfortunately this logical system was applied to the British succession before the sequence of series and stages had been worked out. Thus while $h^{5'}$ corresponds fairly well to the Cenomanian stage, and $h^{5''}$ to the succeeding Turonian, the preceding Albian comprises both h^3 and h^4. So despite its elegance and logic the British system is essentially insular and of local application only.

Logical systems have also developed elsewhere but have taken other forms. Lepsius employed lower-case letters running in alphabetical order, but his sequence ran from *a* (recent alluvium) to *w* Cambrian, *x* and *y* denoting mica-schist and gneiss. This perverse illogicality which gives late letters to early deposits is paralleled by that of the system employed by the U.S.G.S. in its 1911 map of North America (1/5,000,000), in which the systems are designated by numbers running from 1, Pleistocene and Recent, to 18 Cambrian. On the other hand Johannes Walther's map of Germany (1/800,000) of 1920, uses late numbers for late formations as does also the Geological Survey's map of the British Isles (1/1,584,000), 1939. At the other extreme the United States Geological Folios (1/62,500) have avoided sequential indexing altogether. Each formation is indexed by a symbol comprising one capital and one or two lower-case letters: the capital is the initial letter of the system name, and the lower-case letters are chosen from the formation name itself. Thus Jch refers to the *J*urassic *Cah*il sandstone, Cm to the *C*arboniferous *M*onongahela formation. Duplicated initial letters are avoided by the use of Є for Cambrian, K for Cretaceous and Ø for Oligocene. Igneous rocks are included in the scheme Tp referring to the *T*ertiary (Pliocene) *P*inole tuff, and Jsp to *s*erpentinised Peridotite intrusive into *J*urassic strata.

Between the logical systems with their illogicalities, and the logical American avoidance of logicality, stand several hybrids. The French *carte détaillée* at 1/80,000 uses lower-case initial letters of system names (h=*houiller*, m (oligocene and miocene) = *molasse*), with numeral suffixes (arabic numerals in ascending and roman numerals in descending order from the middle of the series) and further suffixial letters to designate specific formations. Several German surveys use similar though less clumsy forms; thus the divisions of part of the Miocene of Baden are designated $m2\alpha$, $m2\beta$, $m2\gamma$, etc. More surprising, the index symbols of the Bologna map fall in this hybrid category, using lower-case initials followed by numerals in ascending sequence, and using letters from the Greek alphabet to indicate special sedimentary phases (e.g. φ for flysch) and for igneous rocks.

These wide and even antithetic variations in what may be considered the systematic

key to a geological map are rather surprising, the more so when it is remembered that an agreed international usage here would make all geological maps intelligible to foreigners. Confronted with, say, a sheet of the Austrian 1/75,000 map from the Vienna district one observes that extensive outcrops bear the index letter ' m '. Reference to the key informs us that formation ' m ' is ' schlier '—a local term as untranslatable as lias or cornbrash—and both age and lithology must be discovered from other sources. On the other hand, faced with sheet M-35-XII of the Soviet 1/200,000 map in which only the formation indexes are not in Cyrillic script, one notes two green outcrops designated Cr_2cm and Cr_2t? followed by a group of yellow outcrops Pg_{2+1}b+k, Pg_2ki, Pg_3h, Pg_3pt+N? which may be fairly readily interpreted as Cretaceous (Cenomanian and ? Turonian) succeeded by Palaeogene 1, 2 and 3, and ? Neogene, the letters ki, h, pt, etc., being evidently derived from local formation names (actually *Ki*ev, K*h*arkov and *Pol*tava). A measure of system in colour indexing here permits some understanding after some detective work ; an agreed international system which would supplement but not replace each national usage, would make all geological maps intelligible to all geologists. Is there not here a subject worthy of discussion by a forthcoming International Geological Congress ?

In view of the divergences already noted it will occasion no surprise to learn that while some surveys—notably those of Great Britain, Württemburg, Prussia and Baden—provide a full and systematically arranged key at the side of the map with the ' colour boxes ' arranged in descending sequence, beginning at the top left, indexed, titled and described, and bracketed by series and system, others fall far short of what can be considered satisfactory. The Austrian 1/75,000 and the Bavarian 1/100,000 (published by Justus Perthes) invert the column, putting the alluvia at the bottom right and the gneisses at the top left : the older Austrian sheets, like the French 1/80,000, arrange the colour boxes in sequence and index them, but offer no clue to their grouping in series and systems, a fault which can only be excused, as in some of the Norwegian 1/100,000, when the true order and age relationships of the rocks are not known.

It is not necessary to examine in detail the many other forms of symbol that are employed on good geological maps. It is obvious that the maximum amount of information should be conveyed regarding the structure and attitude of the rocks whether by dip arrows and related symbols, or by structure contours (as on several U.S.G.S. 1/62,500 sheets and some Prussian 1/25,000 sheets). And it is clear that information regarding water supply (wells, springs, boreholes and hydrohypses), and the economic exploitation of minerals (pits, quarries, shafts, mining concessions, etc.), should be made as full as possible. Many equally good schemes can be devised to achieve these ends, and provided the symbols are clear and explained by an adequate key there are no evident advantages in standardisation. What is apparent, however, when many different series are examined, is how far the poorer series fall short of the best in this regard. This is true even for the most fundamental symbols—those relating to dip and strike—but for other matters the range is even wider, since some maps give no information on them whatever. Prussian maps, for instance, deal excellently with economic information : French maps give an abundance of information which is obscure and out of date : British maps give very little, though the omission is being partly rectified on the newer coalfield sheets : Austrian maps give none at all. A usage which is of interest, but certainly not practicable for British maps, is the Russian method of representing a borehole by a series of concentric circles about 1/40th inch apart, the spaces between being coloured appropriately to the formations passed through.

The Topographical Base Map

In an earlier paragraph it was suggested that the topographic base map must be up to date, sufficiently detailed for the accurate location of outcrops, etc., closely contoured, and ' transparent ' enough not to interfere with the legibility of geological detail. Taking the last point first, it is of course, well known that the U.S. Geological Survey, authorised by Congress as late as 1879, and responsible for both Topographical and Geological Survey, was able to make a great advance in this matter. Early European geological surveys had to be made on the only maps then available, the engraved maps of military inspiration, whose hachures and forest symbols interfered seriously with the geological representation. The Americans had not these difficulties to contend with and designed a topographic map specifically as a base for geological and other overprints, and as its characteristics still make it something of a model they are worth noting. Three colours were, and still are, employed—*blue* for all water features, *brown* for relief including not only contours which are usually at 20 or 25 foot intervals on a 1/62,500 map, but also sand dunes, contour numbers, etc., and *black* for all names and man-made features. Woods

were omitted entirely, as were all special symbols for bridges, mills, churches, and a multitude of special buildings and constructions so characteristic of European maps. Even house dots were omitted from early issues and towns were shown only by the skeletal street pattern; even here the exaggeration of street and road widths was made much smaller than on European maps. This ruthless pruning produced a map which has failed to satisfy all the needs which a topographic map should meet and many of the proscribed details were admitted to later issues; but it also set, once and for all, the standard of transparency in a base map.

There is, however, a complementary aspect to the question of transparency. Topographic detail is useless if it cannot be seen through opaque geological colouring, and different issues vary greatly in respect of the cleanness and transparency of their colours. The more recent sheets of the Austrian 1/75,000 map, printed on a hachured base representing mountain country, stand up to this test very well: the printing is indeed remarkable and deserves a better scale and topographic base. Many Scottish sheets on the other hand have certain outcrops which are quite opaque so that it is impossible to follow the contours beneath, for example, the Torridonian formations of sheet 73, or the Lower O.R.S. andesites of sheet 24. And in these and other cases the difficulties are further increased by the confusion between the engraved woods and the black overprints for the drift deposits.

The loss of the contours in such cases is a serious matter. Whether from the scientific or the practical point of view, the advantages of large scale geological mapping are lost or nullified, if the relationships of the minor solid formations and drift outcrops to the form of the ground cannot be made out upon the map which represents them. Information of value to workers in other fields, such as ecologists, pedologists and geomorphologists, or to such practical men as farmers and civil engineers, is effectively withheld if our geological maps are not clearly and closely contoured and of large enough scale for these relationships to be clearly shown. We have already seen that on purely geological grounds a scale of 1/63,360 is too small. We now note that it is too small also to display adequately the topographical relationships of the mapped geological information.

Finally the topographic information supplied by the base map must be up to date, for although geologists themselves, accustomed to the long vistas of geological time, may not be disturbed by the development wrought by a mere generation or so of urban and industrial land use, practical men who use their maps cannot afford to take such a view. A supplier of sand and gravel desirous of opening a pit in say, the London area, would be woefully misled by the published geological maps. Much or most of the suitable ground there shown as lying outside the built-up area has in fact long since passed under bricks and mortar, or been rendered inaccessible by the development of road plots and industry. A civil engineer who desires geological information on the six-inch scale for Sheffield will find it superimposed on the topographic detail produced by the first six-inch survey of 1851–54: the map, in fact, has very real antiquarian interest. There are of course real difficulties in maintaining an up-to-date topographic base for geological maps. The one-inch topographic map of this country is now in its sixth edition, and some of the preceding editions were but short-lived; the fifth in fact, was never completed for the whole country. No geological survey can be expected to transfer all its data to fresh sheets each time such a change is made in the standard topographic map of the country. Moreover, in Britain, as in France, the change from black engraved maps to colour-printed maps was not helpful to geologists. The newer maps with their coloured roads and woods, their hill shading, and in the French case their purple vineyards and red towns, were not suitable as bases for geological maps, and perforce the latter continued to appear on the old sheets. But while in France those old sheets are still the standard maps of the country and are subject to revision, their British counterparts have long been superseded for topographic purposes, and so have become the veriest fossils, dug up periodically from the depths of the Ordnance Survey for the sole purpose of receiving a geological imprint.

Summary and Conclusions

From this discussion of the characters of a number of existing geological maps it is, I think, possible to re-state the requirements of our ideal geological map in more specific terms than could be used at the outset of this article.

(*a*) In order to give adequate expression to the results of modern geological work in closely settled countries like Great Britain the scale should be of the order of 1/25,000.

(*b*) Considerations of the relation of geological information to both the form of the ground and to such details as fields, buildings, roads, etc., point equally to a scale of this order for the base map.

(*c*) To secure maximum legibility the topographic base should be without unnecessary

detail, and printed in black outline only save for blue water and brown contours: the geological colours should be transparent enough to permit easy reading of the topographical detail.

(*d*) The system of geological colouring should be designed, in addition to meeting this requirement of transparency, to provide an approximate automatic index to geological age, some information as to the lithology of individual minor formations, distinctive treatment of adjacent formations, and special treatment of occasional 'index' horizons. All these ends, I believe, can be achieved by the use of overprinted ornaments on a systematic series of transparent base colours.

(*e*) Every formation shown on the map should be designated by an index symbol and its character and position in the succession precisely and systematically indicated in the marginal key to colours and symbols. The index symbols for bedded rocks should conform, or should be supplemented by symbols which conform, to an agreed international usage. The formulation of such a scheme of indexing would be appropriate to the next International Geological Congress.

(*f*) Adequate information should be given in the form of signs, symbols, etc., on structure, hydrology, economic minerals and their exploitation, and the symbols fully explained in the key. Structural information on the face of the map should be supplemented by one or more sections and a stratigraphical column to scale.

Consideration of these requirements reveals only too clearly that British official geological maps fall far short of the best practicable modern standards. Too small in scale to give expression to all the available information; printed in colours too often muddy and opaque and deriving from a Wernerian fancy that they should imitate the colours of rocks; based on three series of topographic sheets which have long been out of date, with contours no closer than 250 feet on the high ground, and with boundaries which have no relation whatever to those of any series of British official maps now in use, they are open to severe criticism whatever criterion be applied. The moment has clearly come when radical changes in scale, colour treatment and topographic base could be made with advantage. Moreover the moment is opportune for such a change. For the first time in British cartographic history a suitable topographic base map is available—the 1/25,000 series of sheets each 10×10 km. in area and forming an integral part of the new National Grid. The outline edition of this map is already in demand as a base map by workers in all the other field sciences, and either as it stands, or printed in black or in deeper tone of grey to show through the geological colouring, is precisely what is required. Its use carries with it the advantages of close contouring, sheet boundaries that being derived from the National Grid will always be directly related to those of all other published British maps, and the probability that being used for local and national administration it will be maintained by the proposed programme of continuous revision in a reasonably up-to-date condition.

Such a change involves large administrative adjustments, but is not therefore unreasonable. Twice before, when the Ordnance Survey has made changes in sheet lines the Geological Survey has followed suit, the original engraved large sheets of the one-inch map being followed by the 'Old Series' of small engraved sheets, and the 'New Series' of colour-printed sheets. None of these series has ever approached geological completion for the whole of England and Wales, and all remain current for different parts of the country with yet another series for Scotland. It is not thinkable that the revision of the original Geological Survey maps should merely give them conformity with a series of sheet lines long since abandoned for all other purposes, or that the whole should remain perpetually divorced from the National Grid (though bearing it as an additional overprint!) and from all other maps in the country. No advantages derive from delaying the impending change. On the contrary real advantages arise from the adoption of the new scale and sheet-lines. The old sheets covered 216 square miles: the new occupy 100 sq. km., or 38·6 square miles—roughly one-sixth of the old. Survey or revision would occupy only one-sixth of the time and the revision programme be rendered correspondingly more flexible. For example, the revision of one-inch sheet 100 (Sheffield) was in progress before the War, and I have reason to believe that enough was then completed to have permitted the publication of one or more 1/25,000 sheets in the Derbyshire coalfield portion. That information is very relevant to present needs but must wait several more years before publication. It will be urged against the change that the diminution in sheet size raises the number required from some 340 to about 2,000, with increased overall cost of the survey of the country. Such increased cost is fully justifiable because of the increased utility of the maps in practical affairs, and would in any case be largely offset by the reduction in the number (at present very large) of published six-inch sheets. Only in areas of unusual complexity, even in coalfields, would the 1/25,000 scale prove inadequate. Larger

scales are an uneconomic concession to lazy map reading and careless measurements.

British geologists showed the world in the nineteenth century how to make geological maps. To-day our maps are cartographically far behind the best that may be seen elsewhere, but a new opportunity has arisen for a complete overhaul and the adoption of a new basic scale permitting a host of other improvements. It is my hope that this paper by stating the problem may arouse the intelligent interest of British geologists at large and so lead to the development of mature plans and well-considered action.

[*Paper read to Section C (Geology) at Dundee on September* 2, 1947.]

THE LOCATION OF THUNDERSTORMS BY RADIO

By Dr. R. L. SMITH-ROSE

1. Introductory

The most obvious reasons for the location of thunderstorms at a considerable distance from the observing point are utilitarian: namely, to assist in the definition of existing weather, in forecasting weather changes and —more directly—in assisting flying operations. From a more detached standpoint a knowledge of the location of a thunderstorm assists in obtaining a better understanding of factors determining its formation, subsequent movement and development. There has, however, long been another interest in ascertaining the position of thunderstorms, since the energy radiated by lightning flashes is responsible for much of the noise which upsets long distance radio communication and navigational systems.

The investigation of the nature and origin of these atmospheric disturbances in radio communication has been conducted in this country, France and elsewhere for many years past. Formerly this work was of chief interest to the radio physicists and engineers, who hoped that with a knowledge of the main sources of atmospherics, and an understanding of their waveform, some appropriate action could be taken in the design and location of communication systems to mitigate this particular disturbance to radio receiving conditions. The meteorologists were also interested in knowing and understanding what particular phenomena in the terrestrial atmosphere gave rise to the intermittent trains of radio waves known as atmospherics: and discussion has taken place in the past as to whether each atmospheric originated in a lightning flash whether this were visible from the earth's surface or not. Statistical information collected by meteorologists on the frequency and distribution of thunderstorms, and estimates made by physicists of the radio frequency energy radiated by a typical thundercloud discharge, were both in fair agreement with the results obtained by the radio investigator in his observations of the number and field strength of the atmospherics recorded at radio receiving stations.

It will be appreciated that an electrical discharge in the atmosphere radiates an impulsive disturbance which covers the whole of the radio frequency spectrum, and the manner in which such a disturbance is received at a distance depends upon the propagation conditions over the earth's surface and through the atmosphere for the particular band of frequencies to which the radio receiver is tuned. The study of atmospheric disturbances on the radio side must therefore be carried out in close correlation with research into the propagation of waves under various conditions. There are many problems left in this field for the radio investigator which are still being actively pursued in this country and elsewhere.

For the present, however, we may consider that one of the main interests of the meteorologist is in knowing where at any time are the areas of thunderstorm activity around him, and it is in this connection that he has sought the assistance of the radio physicist.

2. The Use of Radar Technique

Before turning to the more direct methods of detecting the actual radiation from lightning flashes, we may deal with a method which is strictly speaking not a thunderstorm locator, but is closely associated therewith. Thunderstorms are generally accompanied by heavy rain or hail, resulting in heavy precipitation of relatively large drops of water or ice. Radio waves of a few centimetres in wavelength are scattered by such drops, the position of which may thus be detected by the echoes they produce on a suitable radar equipment. With the Plan Position Indicator (PPI) type of display now in common use in such radar sets, the position and shape of heavy storm or rainfall areas is shown on the screen of the cathode ray tube with the observing station at the centre. Only one observing station is necessary, and using a

radio wavelength of 3 cm., ranges up to 100 km. or more are obtainable depending upon the detailed design of the radar station and the nature of the surrounding storms. For greater wavelengths the sensitivity of detection decreases rapidly, since the raindrops become less efficient as reflectors ; while at much shorter wavelengths, the waves are more rapidly absorbed by oxygen, water vapour and the cloud of water drops itself, so that the practical range of detection decreases considerably.

While this modern technique will undoubtedly find a very useful place as a radio aid to meteorology, it should be emphasised that it is mainly of use for locating areas of heavy rainfall precipitation, or of convective columns of air holding the drops in suspension, but no information is given as to whether such precipitation has accompanied an actual thunderstorm.

3. The Location of Thunderstorms by Direction Finding

We may now revert to a consideration of the lightning flash and the associated emission of radio waves and consider how these waves may be utilised at a distance to give an indication of their origin. While it may be possible in the future to utilise a knowledge of the strength and waveform of atmospherics and of the varying times of travel of the different component waves, the only scheme which has so far been applied successfully to this problem is the use of a network of three or more direction finders, which by simultaneous cross-bearings can indicate the source of individual atmospherics. Since the information is required essentially for meteorological purposes it is convenient, in order to avoid the interference which would otherwise be caused by signals from radio sending stations, to use a portion of the spectrum beyond that which is normally used for radio communication, broadcasting and navigation.

It is perhaps fortunate also, that a large proportion of the energy of a lightning flash is radiated at very low frequencies, and is thus transmitted to large distances. For these reasons we find that the radio direction finding technique used for the location of thunderstorm activity has been developed on frequencies between 10 and 30 kc/s. corresponding to wavelengths of 10 to 30 km. Interference from the few high-power radio sending stations operating within this band can be avoided by a suitable choice of the working frequency ; on the other hand, by tuning the receiver in turn to the signals from the various stations available and observing their direction of arrival, a limited overall check is obtained on the bearing calibration of the direction finding installation.

Radio direction finding apparatus of two main types was devised and used some twenty years ago by R. A. Watson Watt and his colleagues working under the auspices of the Radio Research Board established under the Department of Scientific and Industrial Research ; and these have formed the basis of nearly all subsequent work in this subject conducted in various parts of the world. These two instruments are the so-called narrow-sector recorder, and the cathode-ray direction finder, and they have been used for a considerable amount of radio investigation work on atmospherics.

(a) *The Narrow-Sector Recorder*

The first instrument comprises a system of closed loops and a vertical aerial with a receiving acceptance arc of a few degrees in azimuth, which rotates slowly about a vertical axis. Any received impulse or atmospheric arising from a lightning flash occurring at a point within the acceptance arc causes a dot to be made on a suitable paper record. This record is attached to a drum which is rotated with the aerial system and is so arranged that the bearing of the lightning flash can be read directly from the record to within a certain tolerance set by the width of the acceptance arc of the receiving system. By slowly traversing the paper each record gives in Cartesian coordinates a picture of the directions of storm activity for a period of 24 hours. Apparatus of this type is useful for indicating the relative thunderstorm activity in different directions, and the general development and movement of well defined storm areas. Although the record is built up of dots, each of which arises from an atmospheric, it gives a statistical impression rather than a practical means of examining individual flashes. It is, therefore, difficult to use an array of such instruments a few hundred kilometres apart to define the position of flashes not located in the well defined azimuthal regions of high activity. Furthermore, because of the limited arc of acceptance, there is only a small probability that any given flash will be recorded on all instruments. It is in this respect that the cathode ray direction finder, which is omnidirectional in its reception characteristics, has the great advantage over this narrow-sector type of recorder. Each flash will be recorded at all the direction finders installed at the ends of suitable base-lines ; observations may be made visually or photographically, suitable arrangements being made for synchronising the observations at the various installations. The position of each flash is obtained by plotting on a map and in this way the general extent and movements of the

storm areas are synthesized. Centres of mild activity are spotted as well as the major ones.

(b) *The Cathode Ray Direction Finder for Atmospherics*

The system applied by the British Meteorological Office in this country during the past eight years embodies the twin-channel cathode ray direction finder with fixed loop aerials oriented at right angles, which is now in widespread use for many radio direction finding purposes. A description of the latest design of this instrument as developed for the Meteorological Office in the Radio Division of the National Physical Laboratory has recently (1947) been published, but a few of the outstanding features may be recapitulated here.

The receiving aerials are of the vertical closed loop type and two of these are arranged orthogonally and connected to identical superheterodyne receivers fed from a common local oscillator. The signal frequency range is from 9–30 kc/s, and the equipment is normally tuned to about 12 kc/s. Arrangements are provided so that adjustments may be made to ensure that the receivers have identical characteristics with the pass band of a few hundred cycles centred about the frequency of tuning. Matched attenuators are provided at appropriate points in the amplifier chains so that the gain of the equipment may be adjusted to suit prevailing field strength conditions. Considerable care has been taken to ensure good linearity of response; as a result signals producing deflections on the cathode ray tube equivalent to four times full-scale may be accepted without introducing appreciable angular error. Bearings are read on the 6 in. diameter screen of a long persistence cathode ray tube, either against a scale marked directly on the tube face or by means of a separate scale and manually rotatable cursor.

Two main types of bearing display are provided. In the first the grid of the cathode ray tube is held at a steady potential, so that all signals are shown; when no signals are present a bright spot is produced at the centre of the screen. In the second type of display, the operating voltage of the cathode ray tube is held below the cut-off condition until the deflection voltage exceeds a certain threshold value; the grid potential is then raised so that the trace is visible for a certain time interval (excitation time). Two values of excitation time are provided and are of the order of 200 μs. and 100 ms. respectively. The net visual result with the second type of display is that atmospherics of amplitude exceeding a controllable length on the cathode ray tube are visible, while at other times the screen of the tube is blank. The second type of display is easier to use, as the operator's attention is not distracted by the welter of small amplitude atmospherics at the centre of the tube; the flashes shown are of high visual intensity and the afterglow is readily observable. With the shorter excitation time the trace is weaker in intensity, but its shape is seldom complicated by the intrusion of other atmospherics.

Tests have shown that the probable error of observation for a good observer is less than 0·5°. Absolute error will be greater than this. It is expected that the installation of equipment of the improved type outlined above in the Meteorological Office network of stations will result in a useful improvement in source location accuracy, over that which has been obtained with the existing equipments, some of which were constructed over ten years ago.

4. Observations on Thunderstorm Location

During the past war a network of three, and later four, stations in the British Isles has been maintained and operated by the Meteorological Office using cathode ray direction-finders of the type described in the previous section. These stations are situated at Dunstable (Bedfordshire), Leuchars (Fife), St. Eval (Cornwall) and Irvinestown (N. Ireland), and they provide baselines from 350 to 700 km. in length and are thus suitable for locating atmospheric sources—or storm areas—at ranges up to about 2,000 km. Regular observations are made for periods of ten minutes every one or two hours during daylight. The stations are connected together by line telephone, for the purpose of synchronising the visual observations and communicating the results to the headquarters station. Only the strongest atmospherics are observed, and the rate of observation is restricted to some five to ten flashes per minute. The results are rapidly plotted and so are immediately available to the forecaster at the chief meteorological station. Their value to short period weather forecasting has already been found to be very great; information furnished by the radio observations is particularly useful in forecasting the movements of thunderstorms and other instability phenomena. In addition, the more systematic study of the results obtained in this manner has enabled the meteorologist to increase his knowledge of the outstanding features of the distribution of storms in this part of the world, and of the phenomena associated with the warm and cold fronts in moving air masses.

For example, it appears that in winter the frequency of storm activity is considerably higher over sea than over land, and that in

summer the frequency of atmospherics over the sea areas falls to a quarter or less of the corresponding frequency in summer. Over land areas, there is a marked rise in the frequency of occurrence of atmospherics during the spring ; it remains high during the summer months and drops rapidly in September. The storm activity indicated by such observations can be attributed to conditions which give rise to atmospheric instability. The centres of activity are sometimes found to be associated with cold fronts, while at other times they are concentrated towards the apex of the warm sector. In another example in which the warm sector in a cyclone had become partly occluded, it was noted that the atmospherics arose much more frequently from along the non-occluded than along the occluded part of the system, the highest frequencies of the sources observed being along and in the rear of the cold front and in the apex of the warm sector near the occlusion point.

But these are merely illustrations of the type of information which the radio equipment supplies to the meteorologist, and it must be left for the latter to investigate the subject with the aid of this new tool which is now in his hands.

5. The Future Trend of Development

(a) *Results of experience already obtained*

The experience gained so far in the application of this particular radio aid to meteorology has shown that while it is most useful, it is subject to a number of limitations and disadvantages. The dispersal of the stations at considerable distances, the manning of these with skilled and trained observers, and the provision of adequate telephone facilities make it an expensive item. At least three, and preferably four, stations are essential, and any improvement in technique which could lead to a reduction in this number would naturally be welcomed. The present visual method of observation imposes certain limitations on the rate at which measurements can be made ; while photographic recording, with which experiments are already in progress, may obviate this difficulty, some slight delay in the application of the data to forecasting may result. It will be clear that the present system involves a process of sampling the conditions prevailing at say, hourly intervals : no permanent record of activity over the whole 24-hour period is obtained. The accuracy of the directional observations given by the present radio equipments is limited by the phenomenon of polarisation error to which loop receiving aerials are subject when receiving radio waves some component or all of which have travelled through the ionosphere. While this occurrence is well known to radio investigators, it has not so far proved practicable to eliminate it at the low frequencies at which these particular direction-finders operate. The latest apparatus described above has certain improvements over preceding types, and this will enable a more critical examination of the phenomenon of polarisation error to be made in relation to atmospherics location, than has been possible in the past.

(b) *Possible future developments*

Until some alternative method of accurately locating the source of an atmospheric, such as was envisaged in Section 3, is brought to a practically useful stage, every effort must be made to improve the existing technique to mitigate or overcome the limitations just described. The main development of the cathode ray direction finding technique using a network of stations will probably be along the lines of increasing the quantity of useful information obtained, and reducing the observational errors accompanying this ; photographic recording may be of assistance here. But an outstanding problem is the provision of means for rapidly and accurately transferring the angular data from the remote stations to the plotting centre, and transforming these measurements into locations on a map.

Whether it will be possible to meet the meteorological user's ideal requirement and concentrate all the location equipment at one point is a matter of speculation. The combination of an accurate direction finder, possibly of the spaced aerial type and free from the sense ambiguity to which the present system is subject, with some means of simultaneously measuring the distance of the source of the atmospheric would be one mode of attaining this ideal. But the measurement of distance instantaneously and at any desired time is not practically attainable at the present day. While in certain limited circumstances the distance an atmospheric disturbance has travelled from its source may be determined from an examination of its waveform, this does not seem to be possible under all conditions. Other parameters associated with the received atmospheric which may yield useful information are its peak amplitude and energy content. It is clear that much further research on the nature and origin of atmospheric disturbances and their electrical properties is necessary before the problems discussed above can be solved to the satisfaction of the meteorologist.

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